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PRAIRIE AND SAVANNA IN SOUTHERN LOWER MICHIGAN: HISTORY, CLASSIFICATION, ECOLOGY

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ABSTRACT

Tallgrass prairie and associated savanna were at their continental boundary in southern Michigan when white settlers arrived and had largely disappeared before scientists could describe them. The historical extent of upland prairie, wet prairie and savanna in Michigan was estimated to be 930,000 ha (2.23 million ac), with savanna constituting 78 percent. In 1830 there were 54 separate locations of upland prairie in Michigan. Historical and modern sources were consulted to locate and visit 66 relict prairies and savannas in 1979–1980. Ordination of these 66 remnants identified several prairie and savanna communities (and a distinct fen community) which varied along three environmental gradients. A moisture gradient ranging from soils of low to high water-retaining capacity formed the series of sand prairie/oak barrens; oak openings; mesic prairie; wet prairie; and fen. A soil texture gradient separated mesic and wet prairies on loams and silt loams (with some sandy loams) from those on sandy loams and sands (with some loams). Soil texture differences generally corresponded to glacial parent material differences: coarser-textured soils were associated with glacial lake plains and to a lesser extent with outwash plains, while finer-textured soils were associated with outwash plains and moraines. A third but weak gradient divided oak openings on south- to west-facing hillsides from those on rolling to level ground. Summaries of species presence, indicator species, and environmental characteristics are provided for each community type (except fens, which were used solely for the purpose of ordinating stands).

Michigan's extensive savannas defined much of southern Lower Michigan and were characterized by a complex interaction of fire, tree canopy cover, and herbaceous plant diversity. Soils, landscape setting, drought, and other disturbances influenced these interactions. The oak grubs found in Michigan's savannas and described by early writers are now understood as essential for perpetuating the tree canopy of fire-maintained savannas.

These remnants represent less than 0.1% of Michigan's historical prairie and savanna acreage. In view of this loss any remnant should be protected, but especially the oak openings, which were a dominant ecological feature of southern Lower Michigan. Since oak openings existed on a large scale, small reserves are insufficient to represent former ecological processes and encompass the majority of animal and plant species characteristic of oak openings. Consequently, conservation groups and natural resource agencies should identify, protect, and restore large blocks of oak openings in southern Michigan, especially those that contain other prairie and savanna plant communities.

KEY WORDS: tallgrass prairie, oak savanna, classification, ecology, environmental history

INTRODUCTION

Michigan's extensive prairies and savannas disappeared in the 1800s before scientists could fully describe them (Chapman 1984), yet early 20th century

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ecologists understood that southern Lower Michigan formed the northeastern continental edge of tallgrass prairie and savanna (Gleason 1917; Transeau 1935; Curtis 1959). Tallgrass prairie extended from the Great Plains at 98 degrees longitude eastward to central Illinois (Risser et al. 1981; Sims 1988), Michigan, Ohio, and Indiana (Transeau 1935; Küchler 1975). Savanna co-occurred with tallgrass prairie (Küchler 1975, Nuzzo 1986). Savanna, a fire-maintained plant community co-dominated by herbaceous plants and trees, was called oak openings or oak barrens by European settlers, depending on the type of soil and tree species (Cooper 1848; Peters 1970a).

Beginning about 1830 in Michigan (Peters 1970b) and later farther west, settlers claimed prairies and savannas before other land and transformed them by plowing, stopping annual wildfires, and initiating season-long grazing. After 1945 residential and other development increasingly displaced agriculture (Risser et al. 1981; Nuzzo 1986; Noss et al. 1995). By 1980 nearly all of Michigan's prairies and savannas were destroyed or drastically altered by agriculture, fire cessation, and development (Chapman 1984).

Given the historical abundance and modern rarity of prairie and savanna in Michigan, their ecological status is of great scientific and conservation interest. This paper classifies Michigan's prairie and savanna communities, describes their history and ecology, and presents the most complete account of Michigan's prairies and savannas to date in order to assist future scientific studies and conservation efforts.

HISTORICAL ACCOUNTS

Settlers, travelers, and scientists reported that upland prairies, wet prairies, and savannas were distinct, prominent, and extensive features of southern Lower Michigan in the 1800s (e.g., Hubbard 1838, Douglas 1839; for a full account see Chapman 1984). Historical documents available from the 1830s to early 1900s ranged from settlers' journals to early scientific accounts. We quote selected passages at length because they are the only source for information about key ecological aspects of the original prairies and savannas and are more useful to the reader when directly encountered rather than filtered by a modern ecologist.

Treeless Prairies and Bur Oak Plains

Michigan's prairies disappeared so quickly that Butler (1947) complained the state gazetteer failed to mention them. Some (e.g., Prairie Ronde at Schoolcraft) are still obvious today due to their flatness and relative treelessness (Figure 1), and their ghosts are encountered in place names such as Youngs Prairie Road and Grand Prairie Cemetery (Figure 2). Most early observers agreed that Michigan's prairies were treeless (Taylor 1855; Anonymous 1877; Coffinberry 1880; Brown 1881; Van Buren 1884; Geib 1907; Wheeting & Berquist 1923).

> The prairie [Prairie Ronde] . . . seemed wondrously beautiful and grand. It was simply in a state of nature, covered with a pretty rank growth of grass, then dry and sere, no tree except the Big Island grove and one or two other small groves (Brown 1881).

FIGURE 1. Land use in 1971 on historical Prairie Ronde. The flat, treeless aspect differs sharply from most of Michigan's rural landscape and resembles central Illinois. View is to the east from 8th St. near V Ave., Kalamazoo Co. (Photo by Richard Brewer.)

> Ascending slightly from the circumference to the center, yet so as to seem full rather than elevated; surrounded with a noble forest whose sharp-cut and perfect line was nowhere so distant as to be indistinct . . . (Van Buren 1884).

Others (primarily early 20th century soil scientists) stated that Michigan's prairies contained scattered bur oak saplings and hazelnut brush (Rogers & Smith 1916; Perkins & Tyson 1926; Deeter & Trull 1928; Moon et al. 1932; Peters 1970a).

These conflicting accounts were due to prairie's early destruction and the existence of bur oak plains, now extirpated from Michigan. Bur oak plains were a type of open savanna often fringing prairies but also located on level plains lacking prairies, notably in Calhoun and western Jackson County (Kenoyer 1940; Wood 1964; Peters 1970a; Hodler et al. 1981; Brewer et al. 1984; Michigan Department of Natural Resources 2003). Those who witnessed Michigan before 1850 agreed that prairies were distinct from bur oak plains and that the prairies were treeless.

> On the one hand stretched bur-oak plains, spread with a verdant carpet, variegated with dazzling wild flowers, without an obstacle to intercept the view for miles, save the somber trunks of the low oaks, sparsely spreading their shadows across the lawn; on the other hand arose the undulations of the white oak openings, with picturesque outlines of swells and slopes, gracefully sweeping and sharply defined in the distance. Then, there lay the majestic prairie, grand in expansive solitude, its fringe of timber, as seen in the distance, resembling a diligently trained and well-trimmed garden parterre (Coffinberry 1880).

Further evidence that prairies and bur oak plains were distinct is seen in the pattern of initial settlement. As Peters (1970b) showed, most of the earliest land claims by settlers in Kalamazoo County were prairie but almost always at the edge so as to include adjacent oak savanna, in which they built their house. Prairie was valued because it required no tree cutting before cultivation; the savanna added wood for fuel, lumber, and fences and acorns for the farmers' pigs. Property combining the two types of vegetation was optimal; nearly all of it was occupied between 1828 and 1830, before land was officially open for sale.

FIGURE 2. Harrison Cemetery in fall 1968, on historical Prairie Ronde, Kalamazoo Co. Michigan's floristically diverse blacksoil prairies survived only in rights-of-way and cemeteries. After the last mowing of the season, stalks of big bluestem, *Andropogon gerardii*, are visible, emerging from persistent roots to overtop the headstones. (Photo by Richard Brewer.)

Types of Savannas

The term "savanna" encompasses several plant communities described by early travellers and settlers: openings, barrens, plains. Savanna simply means a plant community where herbaceous and woody plants co-dominate.

"Opening" as a term for a sparsely wooded area in a landscape also containing forest was used in New England in the 18th century, according to the 1971 edition of the Oxford English Dictionary. In the first third of the 19th century as a flood of settlers encountered the savannas of the Midwest, the combination "oak openings" probably became widely used. Frederick Marryat (1960), an English traveler in America, used the term in its current sense in 1838, describing lightly treed portions of the landscape southwest of Lake Winnebago in Wisconsin. James Fenimore Cooper gave the term national currency with his 1848 novel Oak Openings set in southwestern Michigan (Figure 3).

> The trees . . . were what is called the "burr-oak" . . . and the spaces between them, always irregular, and often of singular beauty, have obtained the name of "openings;" the two terms combined giving their appellation to this particular species of native forest, under the name of "Oak Openings" (Cooper 1848).

Oak openings were savanna, a plant community where woody and herbaceous plants co-existed in more equal amounts than in forest or grassland. Dispersed groves of oaks or continuous tracts of oaks whose crowns barely touched, grew with a dense groundcover of grasses, sedges, and wildflowers. Depending

FIGURE 3. Bur oak plains might have resembled this stand of bur oak (*Quercus macrocarpa*) near Madison, Wisconsin, but with smaller trees. No intact example of this plant community survives in Michigan. Groundcover in all remnants consists primarily of Eurasian forage grasses, goldenrod, and weedy plants. The open architecture of oak tree crowns lets sunlight reach the ground; light patches move with the sun, producing various light levels that allow species of deep shade to co-exist with species needing full sun. (Photo by Kim Chapman.)

on soils and location, settlers called savanna "oak openings," "barrens," or "bur oak plains" (Peters 1970a, 1970b). Oak openings were the common savanna condition, while oak barrens dominated by species in the black oak group were located on sandy soils, and bur oak plains were a savanna on heavier soils, often next to prairies as discussed above (Higgins 1840; Brewer et al. 1984).

> The oak openings are of two types, that characterized by the bur oak, whence the adjacent village of Burr Oak gets its name, and that in which black oak species predominate. The former lies next to the prairies and has a rich, heavy soil, the latter . . . is of a lighter and even sandy soil, though the land is seldom pronouncedly barren (Daniels 1904).

White oak (*Q. alba*) and hickories (*Carya* spp.) were the common trees of oak openings on rolling topography of sandy loam and loam soils. Chinkapin oak (*Q. muhlenbergii*) also was reported as common in oak openings of southwest Michigan by GLO surveyors, who called it yellow oak. The species is now rare in southern Michigan and its dramatic decrease remains unexplained.

Fire in Savannas

Early accounts agree that large portions of southern Lower Michigan presented the impression of an "Englishman's park," a garden, or an orchard. The

early observers concluded that the open forest conditions and absence of woody understory and debris in these savannas were due to annual fires set by Potawatomi and other Indians. They speculated that the fires killed the above-ground portion of oak trees but left the roots alive, creating oak grubs which could quickly grow into trees when fires ceased. They witnessed fire burning the prairies, perceived that fire stimulated the blooming of wildflowers, and took the increase in woody plants after cessation of fire as evidence that prairies were maintained by annual burning (Cooper 1848; Clapp 1881; Brown 1881; Van Buren 1884; Glidden 1892; Geib 1907; Turner 1911). Curtis (1959) presented early accounts which confirm that annual fires also occurred in Wisconsin savannas. The following accounts are from southern Lower Michigan.

> Clumps of the noblest oaks, with not a twig of underwood, extending over a gently undulating grassy surface as far as the eye can reach: here clustered together in a grove of tall stems supporting one broad canopy of interlacing branches, and there rearing their gigantic trunks in solitary grandeur from the plain . . . (Hoffman 1835).
>
> . . . travelers might wind at will through the superb natural park, trampling down only the flowers that in many places created glowing parterres . . . (Hubbard 1872).
>
> . . . On entering these vast plains a traveller is led to believe that it has been Cleard [sic] by the hand of man. These openings are a sandy loom [sic] and are covered with grass & flowers of various descriptions and hues (Everett 1956).
>
> The annual fires burnt up the underwood, decayed trees, vegetation, and debris, in the oak openings, leaving them clear of obstructions. You could see through the trees in any direction . . . for miles around you, and you could walk, ride on horse-back, or drive in a wagon wherever you please in these woods, as freely as you could in a neat and beautiful park (Van Buren 1884).
>
> To-day, for the first time, I saw the meadows on fire. . . . they are burnt over thus annually to make it tender. These fires, traveling far over the country, seize upon the largest prairies, and consuming every tree in the woods, except the hardiest, cause the often-mentioned oak openings, so characteristic of the Michigan scenery (Hoffman 1835).
>
> Though our mode of conveyance for a few years was by ox-team, we could expedite by taking a bee-line (nearly) to the different points, as there was no underbrush (the Indians kept them burned down). . . . In the spring the fire would run through the woods, which warmed up the ground and caused the vegetation to spring up. . . . The flowers covered the earth . . . (Clapp 1881).

The annual fires which prevented a woody understory from developing beneath the oak canopy created savannas with few obstacles to travel and, consequently, the first travel routes between the early white settlements of southern Lower Michigan passed through savannas (Higgins 1840; Van Buren 1884; Peters 1970a; Peters 1970b; Chapman 1984).

Succession of Savanna to Forest

The federal government's removal from Michigan of most Potawatomi Indians by 1840, and the creation of fire breaks by cropland, roads, railroads, and settlements, stopped the annual fires. Michigan's savannas quickly became oak thickets and then forests. The grubs mentioned by Geib, Glidden, and Hoppin are, in effect, a form of long-lived tree seedling which, owing to its large root mass, can grow and reach a fire-proof size more quickly than an acorn seedling.

The word grub in this sense seems to be a 19th century American invention, probably derived from the same word used as a verb, meaning "to dig up" and known from England several centuries earlier.

> The ordinary character of the "openings" is that of a majestic orchard of stately oaks, which is frequently varied by small prairies, grassy lawns, and clear lakes. These magnificant groves were, until within a few years, kept free from underbrush by the passage through them of annual fires, allowing successive growths of herbage to spring up luxuriantly, covering the surface with a profusion of wild flowers and verdure . . . (Hubbard 1838).
>
> As the periodical fires had now ceased for many years, underbrush was growing in lieu of the natural grass, and in so much these groves are less attractive than formerly; but one easily comprehends the reason . . . (Cooper 1848).
>
> . . . though the rural beauty of the country is still unrivaled, little remains of the original character of the openings. This is a result partly of the progress of civilization, and partly of the thick growth of small timber that has covered all the uncultivated portions since the annual fires have ceased, which kept down the underbrush (Hubbard 1872).
>
> The practice of the Indians was to burn the land over every fall, which had the effect not only of keeping the annual vegetation burned off but the young tree growth also. The "grubs" thus formed grew laterally into stools, the tops of which were hardly perceptible among the prairie grasses (Geib 1907).
>
> After the very best job of breaking, a live grub would be left upon every square rod of ground [i.e., a density of 395/hectare or 160/acre]. . . . The enlargement at the surface about the tap root increased with each year's growth of sprouts, until the cap was formed, a foot or more in width, like an underground toadstool. . . . The whole under-surface of this cap was filled with dormant buds, that awoke into activity at once when the standing ones were cut or were burned away. Nature reasserted itself when the annual burnings had ceased and the fittest stem survived and became the tree, or young oak, as we see them today . . . (Glidden 1892).

Formerly a defining feature of southern Lower Michigan, savanna is now one of the rarest of plant communities. The flora of savannas persists at the edges of forests instead of in the interiors; in field corners and in railroad rights-of-way; and at other locations that experience disturbances which prevent trees from forming a closed canopy. All evidence suggests that the flora of the savannas was diverse and contained species today considered to belong in prairies and woodland edges, as well as many that now are considered characteristic of oak forest.

At a meeting of the Pioneer Society at Centreville, Michigan, in 1893, Ruth Hoppin, an experienced naturalist who taught taxonomic botany at Smith College and what is now Eastern Michigan University, was asked to describe "a Michigan oak openings." The plant life she described is now rarely found under the oaks of Michigan's woodlands. Probable identities of plants named by Hoppin are given in brackets.

> Your secretary has requested me to describe the appearance of a Michigan oak openings in its primeval beauty. Such a description would require the eye of an artist and the pen of a poet. Much as I loved those forest scenes, I have not words sufficient to give you an adequate picture of them. The fires had not run through the woods for years, so the wild flowers had been given full possession, and the underbrush, grubs, we called it, had not had time to grow up. The result was, that the woods looked more like an old orchard than a forest. Roads wound at will among the trees making the most graceful curves and pleasing turns. In early summer the grass was overtopped with wild flowers surpassing in beautiful effects the most skillful landscape gardening and city park scenery.

> Blue lupines [*Lupinus perennis*], variegated phlox [*Phlox pilosa*], scarlet painted cups [*Castilleja coccinea*], purple and white erigerons [*Erigeron philadelphicus, E. pulchellus, E. strigosus*], purple cranes' bills [*Geranium maculatum*], blue spider worts [*Tradescantia ohiensis*], yellow cynthias [*Krigia biflora*], senecios [*Senecio plattensis*] and rock roses [*Helianthemum canadense*], tall golden Alexanders [*Zizia aurea*, *Taenidia integerrima* or *Thaspium trifoliatum*] and white meadow rue [*Thalictrum dioicum*], dainty galiums [*Galium boreale, G. pilosum*, etc.] and coarse columbo [*Frasera caroliniensis*], medicinal lady slippers [*Cypripedium calceolus* var. *pubescens*], Seneca snake root [*Polygala senega*] and culver root [*Veronicastrum virginicum*], all these came on together in rapid succession, co-mingling in the wildest profusion, and stretching as far as the eye could reach under the delicate oak foliage. Why try to describe the earlier growth of violets, asters and all their sisters, their cousins, and their aunts. The now nearly exterminated fringed gentian [*Gentiana crinita*] then flourished in abundance. The farmers, in their eagerness to subdue the soil, have destroyed whole families of these harmless plants and have let in others, many of them not pleasing to look at, and much more hurtful than the native species. I see the day coming when there will not be a patch of forest where the child may see the flowers which charmed his parents' eyes. Like buffalo, the deer, the wild pigeon, the Whip-poor-will and the prairie hen, these, too, will soon be things of the past. The last pioneer will soon be gone and with him many of the native plants and animals will soon disappear (Hoppin 1893).

MATERIALS AND METHODS

Location and Extent

We produced two estimates of prairie and savanna location and extent. The first inferred vegetation boundaries from soil and geological maps and historical accounts (Fippin & Rice 1901; Geib 1907; Rogers & Smith 1916; Wheeting & Bergquist 1923; Perkins & Tyson 1926; Kerr et al. 1927; Deeter & Trull 1928; Veatch 1930; Deeter & Matthews 1931; Moon et al. 1932; Moon et al. 1933; Deeter et al. 1934; Veatch 1934; Mick et al. 1951; Veatch 1959; Farrand and Bell 1982). The resulting map (Chapman 1984) was checked for accuracy against maps based on General Land Office (GLO) survey records (such as Kenoyer 1934, Trygg 1964 and Brewer et al. 1984). The second estimate inferred vegetation boundaries from GLO surveyor field notes that were digitized and available from the Michigan Center for Geographic Information, Lansing, Michigan (Comer et al. 1995). These data were compiled from survey records taken at section corners and on section lines during land surveying prior to settlement (1816–1856). Information from the surveys, including identities of witness trees and locations of such features as prairies and wetlands, was mapped and interpreted by ecologists to produce the digital data layer. The GLO survey data were digitized as polygons, checked by ecologists and formatted in ArcInfo 7.2.1. Location accuracy is 80–186 meters. We assembled these data in ArcView 3.1 and aggregated acreages in four classes: black oak barrens, mixed oak savanna, mesic prairie, and wet prairie.

Field Methods

Journal articles, unpublished theses, and local experts were consulted to locate prairie and savanna stands in Michigan. New stands were discovered during field work. Sixty-six prairie and savanna stands were visited in 1979 and 1980 (Chapman 1984). Tree canopy cover in stands was <51%, a level that has been used to separate savanna from forest (Curtis 1959, Brewer et al. 1984). Stands had not been excavated, filled, graded, grazed, or similarly disturbed, and contained <1% non-native species cover (excepting *Agrostis gigantea*, *Phalaris arundinacea*, *Poa pratensis*, and *Poa compressa*) We included fens in the study because differences with wet prairies were not understood. Five stands classified as fens—a plant community on organic soil saturated by calcium- and magnesium-rich groundwater (Curtis 1959) and found in prairie and savanna regions of Michigan—were used in the ordination but are described in detail elsewhere (Chapman 1984).

All vascular plant species, the mosses *Polytrichum juniperinum* and *P. piliferum*, and *Cladonia* lichens were recorded. Sampling avoided forest edges and vegetation transitions created by elevation, soil moisture, or flooding, as recommended in phytosociological studies (Mueller-Dombois & Ellenberg 1974). Species recorded by experts in 23 stands, but not found in our field work owing to the timing of visits, were added. For 13 stands, these additions represented <10% of the total species and for 10 other stands 10–50% of total species. Species names are consistent with Voss (1972, 1985, 1996).

Ordination and Classification

With the goal of identifying modern prairie and savanna plant communities, relationships among stands were determined by calculating Jaccard's coefficient of similarity and constructing a polar ordination of stands along three ordination axes (Bray & Curtis 1957; Mueller-Dombois & Ellenberg 1974). Stands that shared the fewest species were placed farthest apart along the axes. Stands near each other shared a greater number of species. This technique is appropriate for presence-absence data when the underlying environmental gradients are not known (Beals 1973). Endpoints of axes were selected using a manual method (Bray & Curtis 1957; Mueller-Dombois & Ellenberg 1974). The x-axis endpoints were chosen as two stands which were most different (i.e., they had the smallest coefficient of similarity) but which had high coefficients of similarity with other stands. Subsequent axis endpoints were chosen from remaining stands in the same way.

A computer program was written to calculate coefficients of similarity among stands, calculate the ordination position on three axes, and evaluate the performance of the ordination. The performance was analyzed with a Student's t-test of the correlation between stand locations in ordination space (interstand distance) and stand differences based on plant composition (coefficients of similiarity). A subset of 25 stand pairs (about 1% of stand pair combinations in the ordination) was selected and a linear combination of factors for those stands was calculated for each axis and compared to the average coefficient of similarity for those stands.

To aggregate stands into plant communities, clusters of similar stands were identified and compared to other clusters. A reference stand at the center of evident clusters was chosen, an ordination distance was calculated from the reference stand to all other stands, and stands were assigned to the cluster containing the nearest reference stand.

Plant Community Characteristics

For the resulting prairie and savanna plant communities, we calculated the total species found; a mean number of species per stand; the percent presence of each species (i.e., number of stands a species occurs in divided by number of stands in the community); and the percentage of frequent species (i.e., species found in 50–100% of all stands in that community). Sorensen's similarity index (Mueller-Dombois and Ellenberg 1974) was calculated among pairs of plant species as confirmation of community differences (see Chapman 1984).

We selected indicator species for each prairie and savanna plant community to aid in future field identification (Mueller-Dombois & Ellenberg 1974) and restoration efforts. Indicator species were ranked as high – restricted to the community and 80–100% presence; medium-high—restricted to the community and 50–79% presence; medium—restricted to the community and <50% presence; medium-low—80–100% presence and <20% presence in another community; low—50–79% presence and <20% presence in another community.

The environment of prairie and savanna plant communities was described by soil pH, texture, and water retaining capacity (WRC), a measure of the weight of water a soil type can hold when saturated. The pH was measured in the top 5–10 cm of the soil surface using a LaMotte-Morgan field test kit. Soil texture was determined by feel (Thein 1979). To determine WRC, soil cores of 5cm diameter and 8cm depth were obtained and soaked in water for 24 hours, drained for 24 hours, weighed, oven dried at 120° C. for 48 hours, then weighed again and the container tared. WRC was calculated as: [(wet soil – dry soil)(100)]/(dry soil – tare). For each plant community, the mean pH and WRC were calculated and the prevalent soil textures listed. Percent slope, aspect, geological substrate, and land use were also recorded (see Chapman 1984).

RESULTS

Location and Extent

Historical and modern accounts and the soil and GLO survey data agree that prairie and savanna plant communities once dominated large areas of southern Lower Michigan (Figure 4; Table 1). The acreage estimated from soils and geology (Chapman 1984) was less than half the acreage obtained from digitized GLO

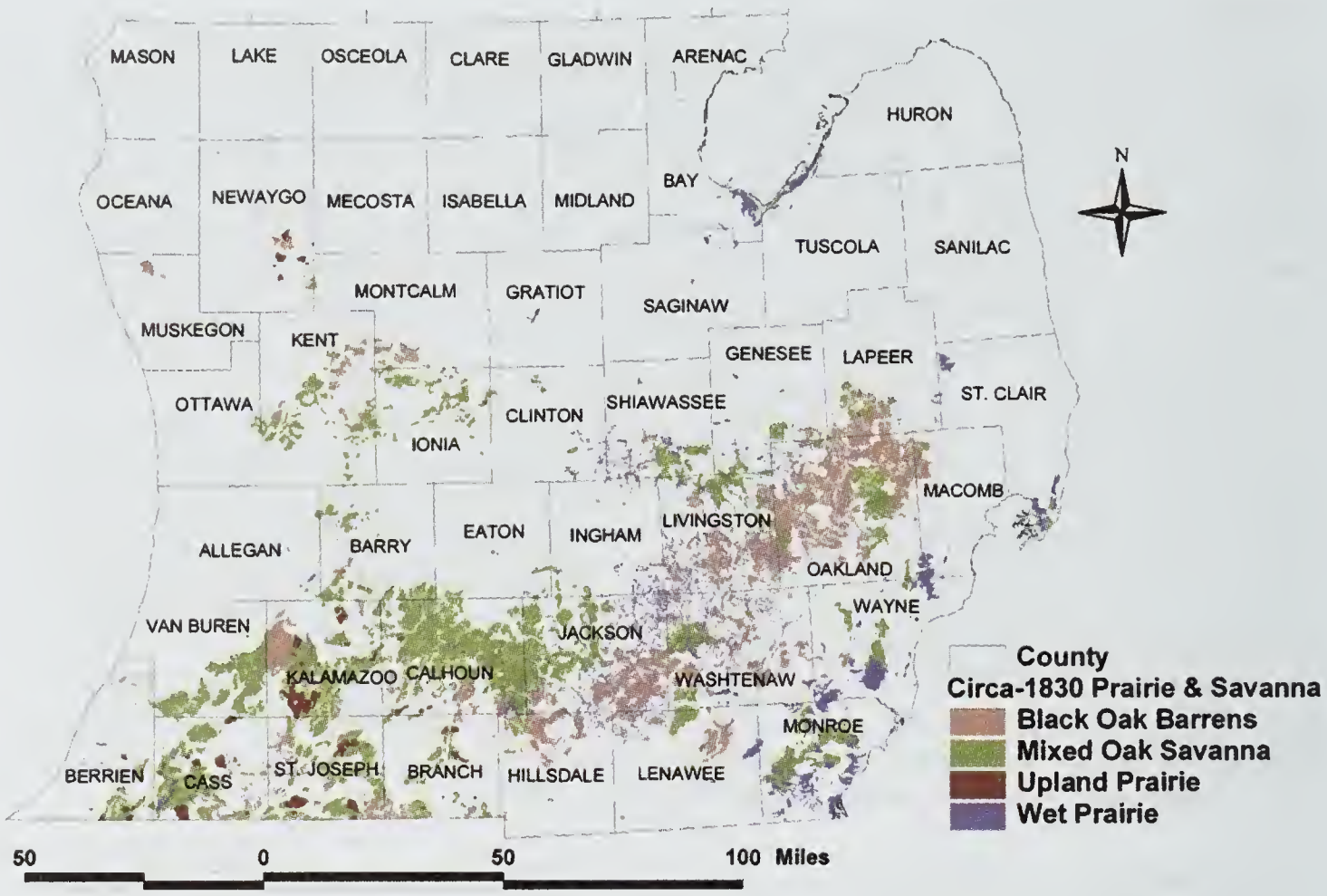

FIGURE 4. Distribution circa 1830 of prairie and savanna in southern Lower Michigan (Comer et al. 1995). Black oak barrens was a savanna on low fertility soils; mixed oak savanna occurred on richer soils.

survey data. The digitized GLO data estimate of Michigan's savannas and prairies was 902,300 ha (2,229,630 ac), with savanna comprising 77.9%. Historical sources identified 54 locations likely to have been upland prairie in 1830, totaling 35,600 ha (88,000 ac) (Figure 5; Chapman 1984). The largest at 5,100ha (12,600 ac) was Prairie Ronde in Kalamazoo County. The GLO digital data estimate for upland prairie was less than Chapman's soils-geology estimate, but also was less accurate because it was calculated from section line data which infer community boundaries beyond section lines, while Chapman's was calculated from soil units on soil survey maps. Wet prairie occupied more area than upland prairie but may have included sedge meadows, fens, and sedge-dominated marshes.

Environmental Characteristics of Prairies and Savannas

The ordinated prairie and savanna plant communities exhibited the greatest variation in species and environment along a soil moisture gradient from sand prairie/oak barrens (see cover), to oak openings, mesic prairie, wet prairie, and fen (Table 2). (A photograph of the ordination and a list of sites are available from the senior author.) This dominant soil moisture gradient also defined the prairies of Wisconsin (Curtis 1959; Umbanhowar 1992), Ontario (Faber-Langendoen and Maycock 1987), and Illinois (White and Madany 1981). Soil moisture and pH were correlated; low pH was associated with low water-retaining capacity soils, high pH with high water-retaining capacity soils.

TABLE 1. Estimated acreage of Michigan prairie and savanna circa 1830.

	Total Acres[1]	Total Acres[2]	Mean Acres[2]
Black Oak Barrens	185,000	722,049	1,668
Mixed Oak Savanna	475,000	1,058,557	1,819
Upland Prairie	88,000	66,192	919
Wet Prairie	112,000	382,832	271
Total	860,000	2,229,630	—

[1]Chapman 1984
[2]Comer et al. 1995; mean acres is of polygons

On a second gradient, soil texture was associated with floristic differences within mesic and wet prairie categories. Soil texture differences generally corresponded to parent material differences. Fine-textured, loamy soils on moraines and outwash plains supported mesic and wet prairie communities, whereas coarse-textured, sandier soils of glacial lake plains and to a lesser extent outwash plains supported mesic sand prairie and lakeplain wet prairie. Umbanhowar (1992) and Faber-Langendoen and Maycock (1987) also demonstrated that soil characteristics (and to a lesser extent geographic location) played a significant role in determining the plant composition of prairie types in Wisconsin and Ontario.

A third but weak gradient separated oak openings on south- to west-facing hillsides from those on rolling to level ground.

The ordination of stands on the x-axis was highly correlated with coefficients of similarity among 25 stands selected for testing ($p < 0.001$), with a mean coef-

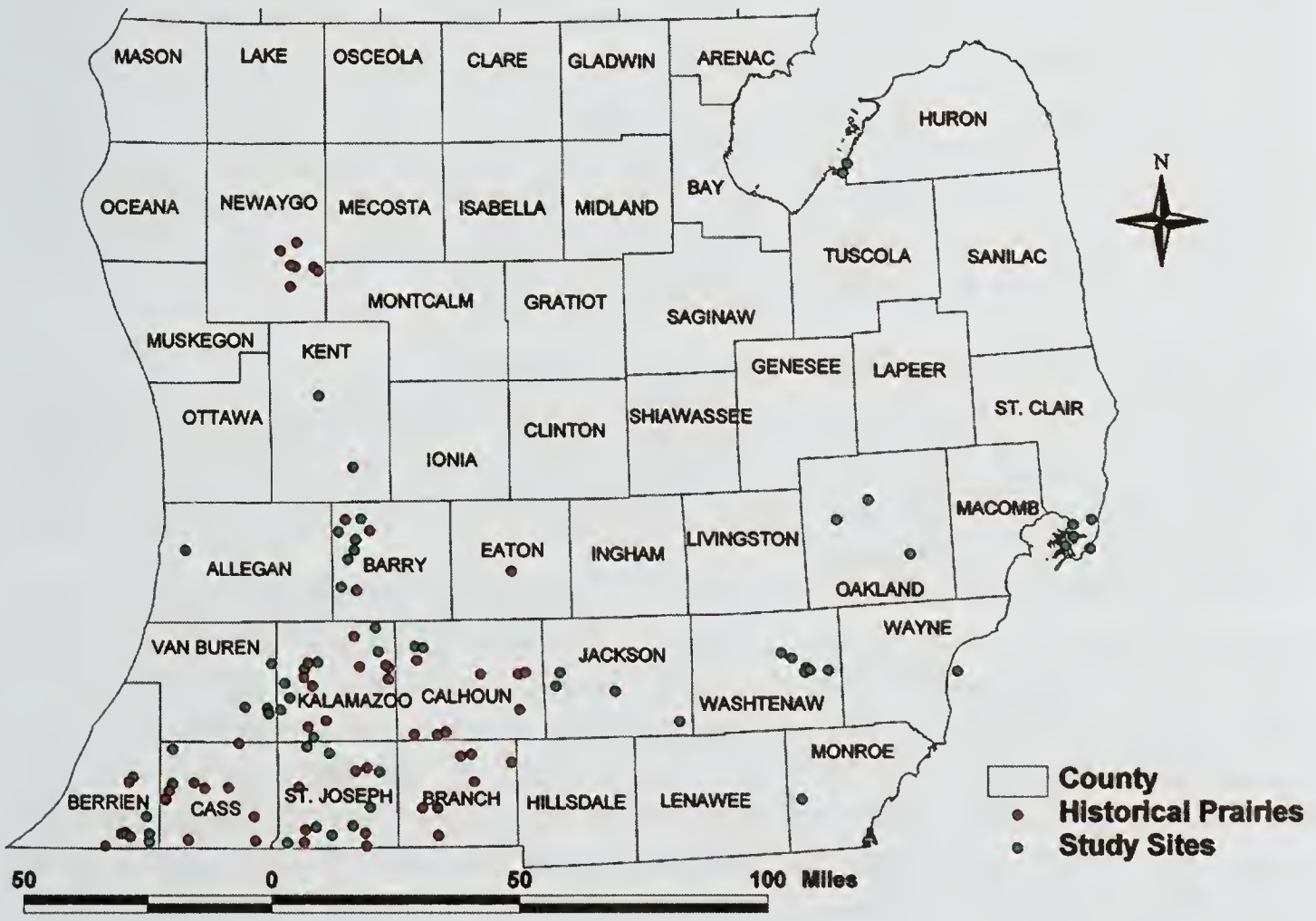

FIGURE 5. Locations of historical prairies identified by early settlers and travellers and in soil surveys; and of study sites used in the ordination of prairie and savanna plant communities.

TABLE 2. Soil characteristics of Michigan prairie and savanna plant communities. (Fen is included for reference as the endpoint of the first ordination gradient.)

Plant Community	Mean pH	Range in pH	Mean WRC[1] (%)	Range in WRC (%)	Common Soil Textures	Other Soil Textures
Dry Sand Prairie/ Oak Barrens	5.1	4.6–5.7	38	28–48	loamy sand	sandy loam
Mesic Sand Prairie	5.5	5.4–5.9	43	31–62	sandy loam	loamy sand, sand
Oak Openings (Hillsides)	5.5	4.5–7.8	51	30–85	loamy sand, sandy loam	none
Oak Openings	5.8	5.2–6.7	54	43–94	sandy loam	loamy sand, sand
Mesic Prairie	6.2	4.9–7.5	64	37–106	loam, sandy loam	silt loam
Wet Prairie	6.9	5.5–7.7	100	43–170	loam	sandy loam, silt loam
Lakeplain Wet Prairie	8	7.7–8.2	60	50–68	sandy loam, loamy fine sand	loam
Fen	7.6	6.8–8.2	432	220–745	sapric muck	none

[1]Water retaining capacity (see Methods).

ficient of similarity of 75.1 (standard deviation 23.3) for the selected stands used in the test. The x-axis endpoint stands had a very low coefficient of similarity (2.7 of a possible 100). The y- and z-axes individually were not significantly correlated with coefficients of similarity for the 25 stands tested. The endpoint stands on the y- and z-axes were more similar than those on the x-axis (coefficient of similiarity 24.1 and 26). Although a linear regression test of variance was not performed, it can be concluded from these simple tests that the x-axis represented the greatest amount of variation among stands, while the y- and z-axes represented a lesser amount of variation. However, the y-axis probably represented significantly more variance than the z-axis judging from the physical separation of stands at the right side of the ordination.

Vegetation Characteristics of Prairies and Savannas

The 66 stands supported 495 plant species and were grouped into seven plant communities which varied in species composition along the three environmental gradients just described: moisture, soil texture, and a gradient related to slope and aspect (Table 2; Appendix 1).

Plant communities varied in the degree of internal species homogeneity, distinctness from one another, and number of indicator species (Table 3; Appendix 1 & 2). Plant communities near each other on the environmental gradients shared more species than plant communities farther apart on those gradients. Sand prairie/oak barrens, wet prairie, lakeplain wet prairie, and fen were the most internally homogeneous and distinctive plant communities and contained the most indicator species. Oak openings was the least internally homogeneous plant community and had the fewest indicator species. Though oak openings supported 237 plant species, only 16.8% of them were encountered frequently and a single plant, *Aster pilosus*, qualified as an indicator species. Oak openings had a

TABLE 3. Plant species statistics in Michigan prairie and savanna plant communities.

Plant Community	Total Species	Mean Species Per Stand	% Frequent Species[1]	Number of Indicators
Dry Sand Prairie/Oak Barrens	182	77	41.8	33
Mesic Sand Prairie	241	79	24.5	20
Oak Openings (Hillsides)	148	49	27.7	14
Oak Openings	237	65	16.8	1
Mesic Prairie	172	81	29.1	25
Wet Prairie	177	69	36.1	24
Lakeplain Wet Prairie	157	76	37.6	26

[1]Frequent species have a presence of 50–100% among all stands of a plant community.

large number of species in common with other upland prairie and savanna communities. Oak openings on hillsides was less internally homogeneous than dry sand savanna/oak barrens and wet prairies, but had a high number of indicator species. Mesic prairie and mesic sand prairie had few restricted indicators but a large number that were at low presence in other plant communities.

DISCUSSION

The prairie and savanna plant communities derived from field data and ordination are consistent with historical accounts, to the extent that comparisons can be made. Adding stands to the ordination and employing a finer level of analysis (e.g., ordinating only the upland prairies and savannas) may reveal finer patterns in species presence among stands. For example, Faber-Langendoen and Maycock (1987) described a wet-mesic sand prairie type in southwest Ontario which exists on Michigan's coastal lakeplains but was not revealed by the ordination. Current ordination software with greater computing power and flexibility (e.g., McCune and Mefford 1999) might also improve the ordination results.

With 495 plant species recorded out of about 2500 vascular plants statewide (including non-native species), Michigan's prairie and savanna flora is large. We think it likely that these species, and others of prairie and savanna affinities, arrived at various times after glacial recession and also that some sites of appropriate parent material and physiography supported vegetation recognizable as prairie well before the mid-postglacial hypsithermal period of 6,000 to 8,000 ybp (years before present) which is widely credited with allowing prairie vegetation to become established in Michigan.

Descriptions of Quaternary vegetation change published in the last 20 years (listed in Grimm and Jacobson 2004) tend to disregard the idea advanced by Gleason (1922a; see also Benninghof 1964 and Stuckey 1981) that the beginnings of the Prairie Peninsula are traceable to the early postglacial of 10,000 to 13,000 ybp (King 1981). Perhaps this neglect stems from an over-emphasis on highly obvious fossil pollen changes of the mid-postglacial that are interpreted as a period when global mean temperature was about 1 C higher than today. At that time prairie vegetation expanded at the expense of forest. Radiocarbon dat-

TABLE 4. Comparison of prairie and savanna classifications in southern Lower Michigan.

Presettlement Vegetation Mapping (Comer et al. 1995)	Ordination of Prairies and Savannas (Chapman 1984)	Michigan Natural Features Inventory Plant Community Classification (Kost et al. 2007)
	Palustrine Prairie & Fen	
Wet prairie	Wet meadow	Southern wet meadow
	Fen	Prairie fen
	Lakeplain wet prairie	Lakeplain wet prairie, lakeplain wet-mesic prairie
	Wet prairie	Wet prairie, wet-mesic prairie, wet-mesic sand prairie
	Terrestrial Prairie	
Upland prairie	Mesic prairie	Mesic prairie
	Mesic sand prairie	Mesic sand prairie
	Oak openings (hillsides)	Hillside prairie
	Oak openings	Dry-mesic prairie
	Dry sand prairie/oak barrens	Dry sand prairie
	Terrestrial Savanna	
Mixed oak savanna	Bur oak plains	Bur oak plains
	Oak openings	Oak openings, lakeplain oak openings
Black oak barrens	Dry sand prairie/oak barrens	Oak barrens
	Not included	Oak-pine barrens, pine barrens

ing has placed the beginning of this prairie expansion at about 7,000 or 8,000 ybp in southeast Minnesota (Wright 1968) and northern and central Illinois (King 1981) and 6,000 ybp in southwest Michigan (Manny et al. 1978).

The palynological signal interpreted as prairie expansion consists of an increase in *Quercus* pollen, a decline in *Fagus* pollen, and an increase in forb and grass pollen. However, because most prairie and savanna forbs and also shrubs are insect pollinated, the fossil pollen record which depends to such a large extent on wind-pollinated species provides only a broad indication of the existence of prairie vegetation and no specificity as to type of prairie.

Curtis (1959) suggested that a portion of the dry prairie flora arrived at a different time than wet prairie, most likely from the southwest, whereas the wet prairie flora was thought to originate in the southeast. It seems possible to us that some form of dry sand prairie that included one or both species of *Ambrosia* (Appendix 1) may have been the earliest of Michigan's prairie communities, developing as soon as one or a few thousand years after the glaciers receded and persisting on highly drought-prone landscapes prior to the expansion of prairie in the mid-postglacial hypsithermal period.

The classification of prairie and savanna in our study is coarser than that of the Michigan Natural Features Inventory (MNFI)(Kost et al. 2007; Table 4) but finer than the presettlement vegetation types available digitally (Comer et al. 1995; Table 4). The greatest difference between our study and the MNFI classification is MNFI's recognition of a wet-mesic prairie community distinct from wet prairie (discussed above). Our study also combined prairie and savanna veg-

etation structure into a single prairie-savanna type for the dry-mesic oak openings type and the dry sand prairie/oak barrens type, whereas the MNFI classification separated these into a prairie and savanna segment on a vegetation continuum influenced by tree canopy shading. The ordination of our study did not include enough savanna stands (due to their rarity and poor quality) to separate prairie from savanna in the analysis. Yet historical data argue that prairie and savanna existed as distinct plant communities. It is the rarity of these types today which prevented a full analysis by ordination techniques.

Dry Sand Prairie/Oak Barrens

As mentioned, these historically distinct types were not separated in the ordination and are discussed together here. At a landscape scale, patches of dry sand prairie often intermingle with extensive oak barrens, although a century of fire suppression has resulted in much oak barrens succeeding to oak forest. The groundlayer and shrubs of dry sand prairie are largely indistinguishable from those of oak barrens, a savanna type supporting an open canopy of black oak (*Quercus velutina*), sometimes with scarlet oak (*Quercus coccinea*, including northern pin oak, *Q. ellipsoidalis*). Little and big bluestem (*Schizachyrium scoparium, Andropogon gerardii*) and Pennsylvania sedge (*Carex pensylvanica*) are dominant groundlayer plants. A close association of dry sand prairie and oak barrens occurs in the oak openings of northwestern Ohio (Anderson 1971).

Dry sand prairie/oak barrens is the most distinctive and cohesive of Michigan's extant prairie/savanna communities (Table 3). Stands share many species and the community has many indicators (Figure 6, Figure 7; Appendix 2). Thompson (1975) also noted that a greater proportion of dry sand prairie/oak barrens species were restricted to the type compared to other prairie/savanna communities.

Dry sand prairie/oak barrens resembles pine barrens (e.g., Houseman and Anderson 2002) and oak-pine barrens (Kost et al. 2007), all of which occur on extremely well-drained soils and possess vegetation that readily catches fire during drought. Dry sand prairie/oak barrens occurs primarily in southern Lower Michigan, while oak-pine barrens and pine barrens tend to occur farther north. Being farther north, the number of prairie species decreases and the abundance of Ericaceae, *Pinus*, and dry-site species such as *Comptonia peregrina* increases in oak-pine barrens and pine barrens.

The most intact dry sand prairie/oak barrens in Michigan are in Newaygo County (Figure 8; Hauser 1953; Chapman & Crispin 1984). Others were documented primarily in southwestern Michigan (Pokora 1970; Scharrer 1972; Schaddelee 1975; Thompson 1983; Chapman 1984). MNFI classifies some of these stands as oak-pine barrens.

The distinct nature and persistence of dry sand prairie and oak barrens may be due to soils and surficial geology. They usually occupy level sites and slopes of glacial outwash plains, sandy glacial lakebeds, and sand deposits in ice stagnation fields and coarse-textured end moraines. Good drainage and low site fertility together with the open architecture of the oak canopy prevent the development of deep shade. However, if fire or other disturbances are prevented, the tree canopy of oak barrens closes, though enough light may reach the ground flora

FIGURE 6. Hairy puccoon (*Lithospermum caroliniensis*) and lupine (*Lupinus perennis*) blooming around May 31 in the oak barrens of Allegan County. These plants often bloom with *Phlox pilosa* and *Asclepias tuberosa*, creating scenes spotted with yellow, blue, pink, and orange flowers. (Photo by Kim Chapman.)

FIGURE 7. Prairie smoke (*Geum triflorum*) is among the early blooming wildflowers in dry sand prairies. (Photo by Kim Chapman.)

FIGURE 8. Oak barrens in Newaygo County. The large trees are scarlet oak (*Quercus coccinea*, which includes northern pin oak) which resprouts from grubs if killed by fire or cutting. Oak brush is visible in the groundlayer. (Photo by Kim Chapman.)

for it to survive in a suppressed condition. The poor site conditions also exclude most Eurasian weeds that compete with native plant species in prairies and savannas. However, knapweed (*Centaurea maculosa*), sheep sorrel (*Rumex acetosella*), and hawkweeds (e.g., *Hieraceum aurantiacum*) can become abundant if soil is disturbed. If trees are removed or thinned by fire or cutting, the ground flora usually recovers quickly (Figure 9; Chapman et al. 1995). This makes dry sand prairie and oak barrens the most easily restored of Michigan's prairie and savanna types (Chapman et al. 1995).

Mesic Sand Prairie

Found typically on glacial outwash, sandy glacial lakeplains, and low sand dunes, the water table that supports mesic sand prairie's distinctive flora is near the soil surface in spring and late fall (Figure 10). Moist soil conditions in the spring and a drying period in mid- to late summer create a unique soil environment which allows dry sand prairie species (e.g., *Danthonia spicata, Helianthemum canadense*) to grow beside wet prairie species (e.g., *Equisetum arvense, Liatris spicata, Pycnanthemum virginianum*). Davis (1908) noted this juxtaposition of species from different soil moisture regimes in his description of mesic sand prairie and savanna on the sand ridges of Saginaw Bay. In northwestern Ohio's oak openings region, Anderson (1971) and Tryon and Easterly (1975) described a similar mesic sand prairie on the lakeplain. In Michigan this plant community is dominated most often by *Schizachyrium scoparium*, sedges (e.g., *Carex pensylvanica*), and *Andropogon gerardii*. When the soil is disturbed

FIGURE 9. Oak barrens in Allegan State Game Area, Allegan Co. A profuse bloom of *Lupinus perennis* in May, 1978, was stimulated by a prescribed burn in April. American columbo also emerged in large numbers after this fire. The fire killed the lower branches of the oaks, increasing the light reaching grasses and forbs beneath the oaks. (Photo by Kim Chapman.)

Agrostis gigantea and *Poa compressa* increase. Shrubs, especially members of Ericaceae, can form dense patches.

Curtis (1959) did not recognize a distinct mesic prairie on sand. Umbanhowar (1992) re-analyzed Curtis' data and found that several of the Wisconsin mesic prairie stands on sandy soils were, in fact, floristically distinct from mesic prairie on heavier soils. Likewise Faber-Langendoen and Maycock (1987) reported the existence of a mesic prairie type on sandy lakeplain soils in southern Ontario. White and Madany (1981) documented mesic sand prairie in Illinois, citing *Scleria triglomerata* and *Aletris farinosa* as indicators. Clearly mesic sand prairie is a distinct and recognizable midwestern plant community containing an assemblage of species found only on sandy soils with a seasonally high water table.

Oak Openings (Hillsides)

Hillsides create distinct microclimates. Steep westerly aspects above lakes and broad valleys afford groundlayer herbs more sunlight at mid-afternoon—the hottest part of the day—than they could receive on level ground. The direct afternoon sun raises ambient air temperature and increases evaporation rates. Curtis (1959) points out that such sites are free of snow earlier in the spring than elsewhere, extending the growing season for early-blooming forbs (e.g., *Hepatica americana, Houstonia longifolia, Besseya bullii*). The soils of Michigan's oak openings on hillsides are always sandy and underlain by glacial outwash, which promotes good soil drainage. Winds from the south and west blow directly at the

FIGURE 10. Mesic sand prairie in Petersburg State Game Area, Monroe County. The sandy soils and seasonally high water table enable plants of wet sites (*Liatris spicata, Solidago riddellii*) to grow with plants of dry sites (*Rudbeckia hirta, Schizachyrium scoparium*). (Photo by Kim Chapman.)

slopes unimpeded by topographic barriers, increasing plant transpiration. These factors intensify soil moisture loss in drought years (e.g., in 1936 and 1989), reducing the growth rates of woody plants. It is this combination of factors that enables plants normally growing in sunny, dry locations (e.g., *Bouteloua curtipendula, Penstemon hirsutus, Phlox pilosa, Solidago nemoralis, Stipa spartea*) to persist surrounded by closed-canopy forests. This unique setting of hillside prairies was recognized by Cole (1901) in the Grand Rapids region.

Oak openings on hillsides are more similar to oak openings on level ground than to other communities, but the surrounding forest strongly influences the flora. Over a dozen species of trees and shrubs frequently occur, and six of the indicators are trees, shrubs, and vines. Herbs of prairie settings persist under gaps in the tree canopy. *Andropogon gerardii, Schizachyrium scoparium, Stipa spartea*, and *Poa compressa* are prominent. *Bouteloua curtipendula* grows in low abundance but is an indicator. Soil erosion on the steep slopes may reduce competition in the understory and allow short-statured herbs to persist (*Houstonia longifolia, Hepatica americana, Phlox* spp., *Campanula rotundifolia*, *Besseya bullii*).

Oak openings on hillsides are small and isolated from each other. Island biogeography theory (MacArthur and Wilson 1967) suggests that small patches of plant communities far from other similar patches should experience high rates of species extinction and low rates of colonization. Indeed, patches of oak openings on hillsides have the lowest mean number of species per stand (49). This level of

richness is the same as in the small hill prairies of Illinois (Evers 1955). Alternatively, the low number of species in Michigan and Illinois hill prairies may be due to the small size of vegetation patches, simply an expression of the species-area phenomenon (Gleason 1922b).

In 1980 the canopy of most stands of oak openings on hillsides was nearly closed, and a layer of understory woody plants grew under the oak trees. Lacking recent grazing, fire, or timber harvest, trees and shrubs cast a dense shade and reduced the cover by shade-intolerant dominant grasses. With the dominant grasses suppressed and competition for surface soil moisture reduced, tree seedling survival increases, setting the stage for further shade suppression. The persistence of grasses and dry-site prairie forbs may have always depended on human intervention. The rough topography and forested setting made it unlikely that, historically, fire could spread to the hillsides from the annually burned prairies and savannas on level ground. Considering their commanding views and exposure to cooling winds, some hilltops were probably Potawatomi campsites and lookouts and may have been burned to maintain open conditions. Today these locations are still preferred home sites. Some stands studied in 1980 have since been damaged or encroached on by home construction.

Oak Openings

More stands exist of oak openings than of any other prairie or savanna community. The oak openings stands that lack trees are now called prairies, but they were derived from the groundlayer of savanna, not treeless prairie. The term oak openings is used here, even for treeless stands, because the plant community probably resembles that of the historical oak openings, except that the shade-tolerant plants that once mingled with shade-intolerant plants in the original oak openings now are largely absent. Though these oak opening remnants are steadily declining, dozens are dotted across the 200-mile breadth of Michigan's Lower Peninsula. The 1830s oak openings formed a continuous belt of vegetation which became the cropland, developments, and closed-canopy forests that characterize southern Lower Michigan.

Three lines of evidence (floristics, soils, community characteristics) support the idea that present-day oak openings originated with the original oak openings vegetation.

Floristics. We envision white settlement in the 1830s setting in motion a successional process that divided the flora of the oak openings into two parts: shade-tolerant species of closed-canopy forests, and shade-intolerant species confined to treeless "prairies." These prairies have persisted at forest edges, in field corners, in cemeteries, on abandoned cropland, and in rights-of-way. The growth of underbrush and shading, which caused the floristic separation, took place in 20 years as noted by writers in Michigan at the time (e.g., Cooper 1848) and documented by Curtis (1959) in historical accounts from Wisconsin.

Daniels (1904) understood that the oak openings flora had become divided into shaded and sunny environments. His list of oak openings plants included species of closed-canopy oak forest (e.g., *Agrimonia gryposepala, Agrostis perennans, Amphicarpa bracteata, Anemonella thalictroides, Bromus pubescens,*

Desmodium glutinosum, Galium pilosum, Elymus hystrix, Sanguinaria canadensis, Scrophularia marilandica, Solidago flexicaulis, Trillium grandiflorum) and of prairies and savannas (*Aster oolentangiensis, Comandra umbellata, Coreopsis tripteris, Elymus canadensis, Galium boreale, Hypoxis hirsuta, Lactuca canadensis, Monarda fistulosa, Phlox pilosa, Rosa carolina, Veronicastrum virginicum*). Some of Daniel's oak openings plants grow in both shaded and sunny locations (e.g., *Geranium maculatum, Hepatica americana, Podophyllum peltatum, Thalictrum dioicum*).

In Ohio's oak openings region Anderson (1971) also documented the presence of herbs that grew in both woods and prairies. Where Anderson (1971) worked, the woods were burned, the woody understory was kept in check, light levels were relatively high inside the woods, and consequently several species grew in both prairies and woods (*Baptisia tinctoria, Coreopsis tripteris, Lupinus perennis, Monarda fistulosa, Sisyrinchium albidum*). Winn and Kapp (1986) observed similar patterns of plant distribution in dry sand prairie and adjacent oak woodlands of west-central Michigan.

Curtis (1959) also documented the differential response of prairie species across a light gradient; some species (e.g., *Amphicarpa bracteata, Aster laevis, Cornus racemosa, Corylus americana, Helianthus strumosus*) were most frequent under the oak crowns where mid-day light levels were below 1,000 foot-candles; some (e.g., *Amorpha canescens, Andropogon gerardii, Helianthus laetiflorus, Schizachyrium scoparium, Stipa spartea*) most frequent between oak crowns or where a tree had died (10,000 foot-candles), and some (e.g., *Coreopsis palmata, Euphorbia corollata, Monarda fistulosa, Solidago ulmifolia*) most frequent in intermediate shade conditions.

Until the cessation of annual burning in the mid-1800s, both shade-tolerant and shade-intolerant plants of Michigan's oak openings grew within meters of each other under varying light conditions caused by different tree densities in the historical oak openings. After burning ceased, light grazing enabled the shade-intolerant plants to persist in woodlands, but when livestock were removed forest succession resumed. As forest succession converted the majority of the oak openings to forest, shade-intolerant plants tended to coalesce into what today are called prairies. There they survived as long as tree cutting, plowing, scraping, burning, or grazing continued at less than destructive intensities.

Soils. While soils of oak openings are generally dry-mesic, the soils are not like those of dry-mesic prairies elsewhere in the tallgrass prairie region. Wisconsin's dry-mesic prairies are on udic mollisols, true prairie soils (Curtis 1959), while Michigan's oak openings occur on udic alfisols, or forest soils. Alfisols have less organic matter in the A horizon, have accumulated irons and other metals in the B horizon due to leaching, and have lower pH than mollisols of typical dry-mesic prairie. These soil characteristics are indicative of long-term forest occupancy, not treeless prairie.

Community Characteristics. Oak openings was the least homogeneous plant community studied, had a single indicator, and shared the most species with other communities. The lack of homogeneity may be related to the large geo-

graphic range of this community compared to other prairie communities; however, oak barrens spans an equally large range, but is more homogeneous. An alternative explanation is that oak openings comprised the extensive matrix in which the other prairie types with their specialized requirements were embedded. The common species of oak openings were those having a wide geographical distribution, broad ecological amplitude, and good dispersal abilities (vagility). Daniels had observed early in the 20th century the spread of oak openings plant species into the unused portions of the landscape: fencelines, hedgerows, pastures, forest edges, and roadsides.

> The flora of the oak openings is gradually becoming general to the whole upland region. Groves have been planted or encouraged to grow even in the prairie district, and the hardy autumn vegetation springs up in fence corners, and survives in some fashion the frequent pasturings (Daniels 1904).

Many oak openings species also grow in other prairie/savanna communities, colonize disturbed ground, and persist despite continuing disturbance (e.g., *Achillea millefolia, Anemone cylindrica, Asclepias tuberosa, Aster laevis, Aster oolentangiensis, Aster pilosus, Erigeron strigosus, Euphorbia corollata, Lespedeza capitata, Rudbeckia hirta, Solidago nemoralis, Solidago speciosa*). The total effect is a lack of distinctness in the oak openings community.

The large number of trees and shrubs in the oak openings of this study (Appendix 1) also supports the idea that modern oak openings is derived from historical oak openings. Davis (1904) listed thirty-five species of trees, shrubs, and vines as characteristic of oak openings and Curtis (1959) noted the large number of shrubs in his oak openings type compared to prairies.

Oak openings of this study had fewer graminoid species compared to other communities, but this may be due to the loss of shade-tolerant grasses from oak openings stands. The groundlayer of current oak openings is dominated by *Andropogon gerardii, Schizachyrium scoparium*, forbs, and in some stands *Poa pratensis*. By contrast Daniels (1904) said that the groundcover of oak openings included several sedge species and woodland grasses (*Agrostis perennans, Bromus ciliatus, B. latiglumis, B. pubescens, Elymus canadensis, E. striatus, E. virginicus, Festuca nutans, Hystrix patula, Muhlenbergia schreberi, M. sylvatica, M. tenuifolia, Panicum latifolium*).

Vegetation Change. Our imperfect understanding of oak openings has prevented scientists and conservationists from fully understanding how to restore and manage it. The central question of restoration and management hinges on how changes in canopy closure influence changes in the shrub and groundlayer, and vice versa.

All evidence suggests that oak openings were diverse structurally and hence floristically. Soil moisture and texture played a role in the distribution of oak openings plants, but we believe that more significant variation in flora depended on the amount of tree canopy as demonstrated in a study of the grassland-savanna-forest gradient in central Minnesota (Chapman and Reich 2007). Where it was sparse, oak openings probably looked like prairie and where it was dense it resembled modern dry oak woodland. Different herbs and the height and extent

of the shrub layer waxed and waned depending on the time since the last fire, the severity of the fire, cycles of wet and dry weather, and herbivory.

Curtis used 50% tree canopy cover to separate forest from savanna, but this dividing line was admittedly arbitrary (Curtis 1959: 92). Early writers described Michigan oak openings as varying from scattered trees to nearly closed canopies (Chapman 1984). Estimates of tree density in vegetation identified as oak openings ranged from 10 to 120 trees/ha (4.4 to 49 trees/ac) (Beal 1904; Wing 1937; Gordon and May 1959). Using GLO data from Kalamazoo Co., Brewer and Kitler (1989) concluded that bur oak savannas had tree densities mostly in the range from about 2 to 24 trees/ha (about 1 to 10 trees/ac); mean density was 7.2/ha (just under 3/ac). What canopy cover these densities yield depends strongly on crown sizes. Crown size ("maximum crown area") is tightly correlated with trunk diameter at breast height (dbh) in open-grown oaks and hickories, according to Law et al. (1994). Based on this relationship, 50% canopy cover for trees of 61cm (24in) dbh is provided by 33–34 trees/ha (12–13 trees/ac). Fifty percent canopy cover for trees of 30.5 cm (12in) dbh—more more closely representative of white and bur oaks in the Original Land Survey data for Kalamazoo County—requires about 111 trees/ha (45 trees/ac). In sum, we can conclude little more than that presettlement oak savannas showed broad, interrelated variations in tree density, tree diameter, and canopy cover.

The dynamics of canopy closure and re-opening revolve around a central question. In a fire-maintained system how do grasses and trees co-exist? Over thousands of years the trees should be killed and fail to perpetuate themselves because frequent fire prevents tree seedling establishment.

To answer this question for South African savannas, Higgins et al. (2000) created a model based on tree life history traits—especially resprouting capacity and stem growth rates—and empirical data on fuel loading and seedling establishment. Adult trees died at a low, constant rate; establishment episodes to offset this loss occurred infrequently. Drought during the growing season was the main limitation for seedling establishment. The simulations highlighted the role of what the authors (following Bond and van Wilgen 1996) called "gullivers" and Americans call "grubs." Storage of reproduction as grubs in the African study proved to be essential to the persistence of trees in savannas. When the storage term was omitted from the model, the population growth rate of trees was zero or negative. The last factor in the model is fuel loading. On dry sites, dead grasses and other plants that provide fuel accumulate slowly and fires are less frequent. Here grubs can escape fire and enter the canopy more often, but fires are catastrophic when they occur, killing many trees. On moist sites, fuel loading is high, and fires can be ignited annually, consuming all woody material over time except trees with fire-resistant bark. (The lack of downed woody material in Michigan's oak openings and bur oak plains was often noted in early accounts.) If grubs are present in moist savanna, they resprout but reach the canopy only in rare periods of higher rainfall or continuous grazing when fire is excluded. The African model showed fluctuations in both grub and tree densities over time in all moisture regimes, but the fluctuations were mild in moister savannas and large and erratic in dry savannas.

Michigan's savannas correspond well to this model. Moist savanna (i.e., bur

FIGURE 11. Bur oak owes its fire tolerance in part to corky wings on the branches, as well as a thick bark on the trunk. (Photo by Richard Brewer.)

oak plains) involved a long-lived, slow-growing, thick-barked tree that survived the intense annual fires caused by rapid accumulation of fuel (Figure 11); tree seedling establishment occurred in wet climatic episodes or perhaps when dense herds of grazers reduced fuel loading. Bur oak plains may also have contained black and white oak brush at the time of settlement (Brewer and Kitler 1989). Dry savannas (i.e., oak barrens) consisted of shorter-lived, faster-growing, thinner-barked trees (e.g., black oak, northern pin oak, scarlet oak) that were top-killed by less frequent but catastrophic fires occurring during drought; these red-oak group trees have excellent resprouting capacity and rapidly grew to large trees between catastrophic fires. (Life history traits of oaks are summarized in Fowells 1965.) Oak openings, dry-mesic in soil moisture, were dominated by white oak which is intermediate in fire susceptibility between bur oak and the red oak group (Curtis 1959). Here, intermediate fuel loading allowed the possibility of annual but less intense fires than in bur oak plains, sufficient to top-kill saplings of the red oak group that were present.

Fuel loading and fire intensity were affected by setting: dry savannas tended to occur on infertile, dry, sandy, level sites such as outwash plains and channels, and sandy lakes plains. Moist savannas occupied level, moist, rich sites, such as the edges of Prairie Ronde. Oak openings were found on rolling and steep topography with better drainage than bur oak plains and more fertile soils than oak barrens.

A good store of grubs is essential to perpetuating the canopy in the African model. As we have seen, oak grubs were widely reported as present in Michi-

gan's oak openings and other savannas. White settlers remembered for the rest of their lives the effort required to dig the huge root masses out of their fields (Chapman 1984). Glidden (1892) implied that oak grubs grew at a density of 395/ha (160/ac).

Historical accounts widely reported that frequent burning of savannas kept oak grubs in a constant state of resprouting. When the frequent fires ceased, the oak grubs rapidly grew to saplings and eventually trees within 20 years of fire cessation (e.g., Cooper 1848; Curtis 1959). Locations where all trees were top-killed by catastrophic fire were called "brush prairie" or "brush savanna" (Curtis 1959). In Michigan these are represented by level, dry sites such as the Oxford Plains in Oakland County (Drake 1872) and portions of the Allegan and Newaygo Sand Plains, and also by level, moist sites where the city of Kalamazoo was founded (Turner 1911).

> There is quite an idea that this village site [Kalamazoo] was a grassy plain with scattering bur oaks; but it was a plain covered with a thick and tall hazel brush, so thick that I have seen a wolf jump up so as to see what caused the row he heard; and the burr oaks were very small, little more than grubs (Turner 1911).

In most savanna situations, fire is an essential element in perpetuating the tree-herbaceous mixture (Higgins et al. 2000; Daly et al. 2000). As we have seen, storage (in the sense of Warner and Chesson [1985]) of tree layer species as grubs is crucial for the continuing survival of the tree component. The other side of the savanna paradox is how, after a period in which the absence of fire has produced continuous shade, grasses and forbs manage to return when fire again becomes prevalent. We suggest that storage is also a major element in this process.

The appearance or reappearance of long-unnoticed prairie/savanna forbs and grasses following fire or tree thinning in forested sites has been frequently reported by restorationists. Although the soil seed bank is one obvious possible source, studies that have evaluated the seed bank suggest that its potential contribution is low (Kline and McClintock 1994; Rosburg et al. 1994). Still, the findings of Stritch (1990) and Rosburg et al. (1994) show that a few prairie and, especially, savanna species may have at least limited representation in the soil seed bank. For most species, however, storage is evidently in the form of underground plant parts. Close inspection of the forest floor in former prairie or savanna sites reveals various species represented by small, often flowerless above-ground plants which retain sizable roots or underground stems (McCarty and Hassien 1986). After the reintroduction of fire, these may be transformed into large, vigorously flowering specimens (Stritch 1990). Probably some individual plants are completely cryptic, with no above-ground parts.

Even in the absence of fire, the death of individual oak trees or branches can contribute to the persistence of shade-intolerant species by opening gaps where these species may expand or possibly colonize. Such holes in the canopy result from ice storms, windthrow, tornados, fungal disease, and in the past passenger pigeon nesting and roosting.

The distribution and abundance of shade-tolerant and shade-intolerant species likely varied at the same location over time. Herbs and shrubs varied in vigor when light levels changed due to disturbance or lack of it, but may have per-

FIGURE 12. Basal rosettes of American columbo, *Frasera caroliniensis*, a long-lived perennial that blooms once when conditions are favorable, then dies. This life history trait and others adapt it well to the temporally and spatially varying tree canopy cover of the oak savanna ecosystem. (Photo by Richard Brewer.)

sisted at some locations for centuries (Figure 12). Shade-tolerant species are favored on north-facing slopes which receive no direct sun and are less likely to burn due to cool, moist conditions and light fuel loads. Conversely, shade-intolerant species are likely to be present on the sunnier slopes where more sunlight reaches the ground, creating warm, dry conditions and making such sites more liable to carry fire.

Different disturbances in different physiographic settings probably created a great variety of vegetational structure in the oak openings setting. Included were areas of widely spaced oak trees, sometimes with crowns nearly touching, but allowing much light to reach the ground due to openness of oak branches; prairie islands and oak groves of many sizes spotted through the savanna matrix; and brush savannas of resprouting oaks, shrubs, and grasses. Herbaceous plants would be distributed based on their light requirements. But the pattern of the landscape would also vary in time, based on types, severity, and recentness of disturbance. Today the small size of oak openings does not allow scientists to understand fully the structural and floristic dynamics of the original oak openings as created by landscape-scale fires.

Mesic Prairie

In the 1830s Michigan's upland prairie was nearly all mesic prairie which is today the rarest prairie type (Figure 13). Several mesic prairies documented by

FIGURE 13. Thompson Road Prairie, Howard Twp., Cass Co., in 1970 before right-of-way maintenance switched from burning to bulldozing and herbiciding. In the 1970s this site supported the richest collection of mesic prairie species in Michigan, and may still do so since the remnant persists. (Photo by Richard Brewer.)

Scharrer (1971) were destroyed when Amtrak and ConRail upgraded their lines in the 1970s and 1980s (Kohring 1981).

Mesic prairie is a distinctive type, with 25 indicator plants (Figure 13). *Andropogon gerardii*, *Schizachyrium scoparium*, and a variety of forbs dominated mesic prairies and *Spartina pectinata* may be abundant in depressions of these otherwise level sites. Michigan's mesic prairies were intermediate in soil conditions among prairie types, and possess nearly the same pH and water retaining capacity as Wisconsin mesic prairie (Curtis 1959). The neutral and moist soil conditions allowed species that grow in wet or dry locations to co-occur. Species frequent in wet prairies (*Silphium terebinthinaceum, Solidago altissima, Spartina pectinata, Thalictrum dasycarpum, Veronicastrum virginicum, Zizia aurea*) grew with species of drier sites (*Helianthus occidentalis, Lithospermum canescens, Solidago rigida*).

One feature involved in determining the set of species that constitutes mesic prairie was discussed by Brewer (Figure 14; 1985). The height of plants in flower increases progressively through the year. Plants flowering in the April 5–June 14 period averaged 0.75m in height; in June 15–July 31 they averaged 2.3m; and August 1–October 20 they averaged 3.7m in height. The species that fit this height-flowering season pattern are the characteristic members of the mesic prairie flora. Consider a species that flowers at short stature in mid-summer. If insect pollinated, it would be unsuccessful because its flowers are less noticeable to insects. If wind-pollinated, pollen exchange would be limited because the flowers are submerged in the calm air within taller foliage.

FIGURE 14. Spring 1963 view of Oshtemo Fruit Belt Prairie, Kalamazoo County, studied by R. Brewer. Articles (1984, 1985) in *The Michigan Botanist* refer to the roadbed (center of photo), the slope (left side of photo), and ridgetop (the flat strip not visible left of slope). This site supported mesic and dry-mesic prairie plant communities. (Photo by Richard Brewer.)

Origins. In forested regions such as Michigan, drought, wildfire, and location contributed to the origin and persistence of prairie. The existence of historical and extant mesic prairies (and the now vanished bur oak plains) has been attributed to their occurrence on level outwash plains (Robinson 1969). Documented historical wildfires are associated with drought conditions (Curtis 1959; Pyne 1982). After the Wisconsinan glaciers retreated from southern Michigan beginning 13,500 years ago, several warmer periods interspersed with cooler periods occurred in Michigan and adjacent states around 10,000 ybp, 7,000 ybp, 4,500 ybp, and 900 ybp (King 1981; Smith and O'Shea 2002). In these warmer periods the dominant vegetation shifted from fire-intolerant species (e.g., spruce, fir, hardwood forest) to fire-tolerant species (e.g., pine, oak, grasses). Beginning around 10,000 ybp American Indians facilitated this conversion by their use of fire, a practice that continued until European settlement. During warming periods, drought-induced catastrophic wildfire, assisted by Indian-set fires, is likely to have destroyed forests and created grasslands and savannas.

The well-drained gravel and sand deposits of outwash plains experience soil moisture loss during drought to a greater degree than glacial till regions in southern Michigan (Robinson 1969). The level surface of outwash plains and lack of natural fire breaks would also allow fires to spread over the entire surface and reach surrounding forests. Thus outwash plains, drought, and fire together may be responsible for the creation and persistence of prairie in Michigan despite the present-day moist climate that favors forest over prairie (Robinson 1969).

Why did some outwash plains become treeless prairie and some bur oak plains? Both historical prairie locations and bur oak plains today support hardwood forests containing maple and other mesophytic species. One possibility proposed by Curtis (1959) is that treeless prairies were created by catastrophic wildfire where mesophytic forest species dominated and oaks were absent. Conversely, where bur oak was present in mesophytic forests, catastrophic wildfire resulted in a savanna containing bur oaks. Dry-site oaks (*Q. velutina, Q. coccinea*) were probably absent from the mesophytic forests while others (*Q. alba, Q. rubra*) could not survive the subsequent high intensity fires occurring on these level sites.

Following this concept, Prairie Ronde, Michigan's largest prairie, originated when mesic forest was destroyed by catastrophic fire. Indeed, the west side of Prairie Ronde is adjacent to a large area of beech-maple forest (Hodler et al. 1981; Brewer et al. 1984). By contrast, the east side of Prairie Ronde is adjacent to an oak savanna region (Hodler et al. 1981; Brewer et al. 1984), with bur oak savanna located closest to the prairie. In this scenario, catastrophic wildfire at the east side of Prairie Ronde affected forests containing oaks, resulting in oak savanna rather than treeless prairie. Catastrophic wildfire in another, westward section of the mesic forest (the future Prairie Ronde) led to treeless prairie. Later wildfires within Prairie Ronde, ignited annually by Indians and facilitated by the level surface of the outwash plain, contributed to the persistence of the treeless prairie, the bur oak plains, and probably also the oak openings to the east. These later fires, propelled by westerly winds, would have eaten into the beech-maple forest west of Prairie Ronde only slowly or not at all.

Jones (2000) documented savanna creation from forest on Manitoulin Island, Ontario. Bur oak savanna was created following a catastrophic 1865 wildfire in a maple-basswood-red oak-ironwood forest. That fire was exacerbated by extensive blow-downs of the shade-tolerant hardwood trees due to their shallow rooting on thin soils over bedrock. It seems possible that some combination of blowdown and fire could have been important in conversion of mesic forest to bur oak plain or mesic prairie in southern Michigan. Windthrow is a frequent occurrence on flat till areas of heavy soil (Brewer and Merritt 1978) as well as thin outwash overlying till.

Historical Versus Extant Mesic Prairie. Some of Michigan's historical mesic prairies occurred on udic mollisols, true grassland soils with a deep, dark, organic-rich upper horizon formed under grass (U.S. Soil Survey 1960). Veatch (1927) recognized that Michigan's historical prairie soils resembled those found in the prairie regions of Illinois. Prairies on udic mollisols disappeared because they were excellent agricultural land. However, Michigan's extant mesic prairies are on udic alfisols, forest soils with a brown upper soil horizon that formed under forest cover (U.S. Soil Survey 1960).

We believe that Michigan's extant mesic prairies studied here derived from the shade-intolerant segment of the bur oak plains flora. This may explain why Michigan's extant mesic prairies share few indicator species with Wisconsin's mesic prairies (Curtis 1959; Chapman 1984). Instead, Michigan's extant mesic prairies are most like Wisconsin's oak openings plant community. However, they are dis-

tinct from Michigan's oak openings community, which occurs on dry-mesic, coarse-textured soils and rolling topography, and was usually dominated by white oak, not bur oak. Michigan's extant mesic prairies also contain a large number of woody plant species and herbs (e.g., *Cacalia atriplicifolia, Frasera caroliniensis*) that are strongly associated with woodland and oak forests (Voss 1996).

Today's mesic prairies were probably created when railroads were built in bur oak plains between 1838 and 1850 and before grazing and farming destroyed the groundlayer of the adjacent bur oak openings. Trees were cleared from the rights-of-way during railroad construction, and afterwards fires were ignited by locomotive sparks and (as recently as the 1950s) by maintenance crews, killing woody plants. These disturbances enabled groundlayer herbs, grasses and sedges to colonize from the increasingly shaded adjacent bur oak plains communities, and over decades the frequent fires preserved the shade-intolerant groundlayer herbs, grasses and sedges in the rights-of-way. Meanwhile forest succession eliminated the shade-intolerant flora from bur oak openings, and agriculture destroyed all vestiges of nearby prairie vegetation. Only in cemeteries from the early settlement period (e.g., Harrison Cemetery near Schoolcraft in Prairie Ronde, Figure 2) can the original mesic prairies of Michigan be found today.

Wet Prairie

Michigan's wet prairies represent a segment in a complex environmental-floristic gradient that includes wet meadows and fens. The indicator species of Michigan's wet prairie, and importance of *Calamagrostis canadensis* and sedges, suggest it is more like Wisconsin sedge-dominated wet meadows than grass-dominated wet prairies (Curtis 1959; Brewer 1965). Wet prairie in Michigan is found on mineral soil and has indicator species that are absent or uncommon in sedge-dominated wet meadows (Figure 15). Michigan's wet prairies support prairie grasses (*Spartina pectinata, Sorghastrum nutans, Andropogon gerardii, Schizachyrium scoparium*) which vary in abundance depending on elevation above flood level. *Calamagrostis* and sedges (*Carex bebbii, C. stricta*) are important in wet prairie, but not to the exclusion of other grasses.

Indians reported that beaver created extensive wet prairies on the flat glacial lakebeds of southeastern Michigan (Hubbard 1838), suggesting that flooding was important in wet prairie creation and persistence. Curtis (1959) also noted that wet prairies were frequently flooded. Today wet prairie is found chiefly along streams, rivers, and lakeshores, which are difficult to drain and use, and less commonly in upland depressions of outwash plains, which are easier to modify for agricultural use.

Relation to Wet Meadow and Fen. Past researchers (Pepoon 1907; Gleason 1917; Kron 1982) did not agree on definitions of wet prairie, wet meadow (or sedge meadow), and fen (or prairie fen) in southern Lower Michigan. Kost et al. (2007) provide technical guidance for distinguishing these three distinctive plant communities.

Wet meadows in southern Lower Michigan have neutral water chemistry like wet prairie, but unlike wet prairie they occur on organic soil as fens do. Wet meadows are dominated by *Calamagrostis* and sedges and lack the prairie

FIGURE 15. *Anemone canadensis* is one of the first wildflowers to bloom in Michigan's wet prairies. (Photo by Kim Chapman.)

grasses found in wet prairies. Fens in southern Lower Michigan, Illinois, and southern Wisconsin occur on muck soils saturated by alkaline groundwater and are dominated by prairie grasses, other grasses, and sedges in varying proportions (Curtis 1959; White & Madany 1981; Chapman 1984).

Curtis (1959) proposed that a large portion of the wet prairie flora originated in the southeastern United States and arrived in our region at a different time than the dry prairie flora. In this scenario, Michigan's wet prairies should be more similar to wet meadows of New York state than wet prairies of Wisconsin, which they appear to be.

Gleason (1917) studied a fen six miles north of Ann Arbor that he called wet prairie for its similarity to northern Illinois wet prairie. The fen was level, had few shrubs, was dominated by grasses, and supported species Gleason learned while studying at the University of Illinois (e.g., *Andropogon gerardii, Helianthus grosseserratus, Lilium philadephicum, Oxypolis rigidior, Phlox pilosa, Silphium terebinthinaceum, Sorghastrum nutans, Sporobolus heterolepis*). However, the Ann Arbor site was on Houghton muck, a typical fen soil, while wet prairie in Michigan and elsewhere is on mineral soil. Illinois and Wisconsin wet prairies are more alkaline than Michigan's wet prairies, and support calciphiles restricted to fens in southern Lower Michigan (e.g., *Cypripedium candidum, Gentiana procera, Muhlenbergia mexicana, Solidago ohioensis*). Other species

in Gleason's prairie are restricted to fens and bogs in southern Michigan (*Parnassia glauca, Potentilla fruticosa, Sarracenia purpurea, Tofieldia glutinosa*).

Curtis noted that fen appeared to be a hybrid of plant communities, and Gleason's "wet prairie" exemplifies this. Besides the calciphiles and fen/bog plants mentioned above, species of southern Michigan bogs (*Betula pumila, Rhamnus alnifolia, Sarracenia purpurea, Solidago uliginosa, Toxicodendron vernix*) and alkaline moist Great Lakes shorelines (*Cladium mariscoides, Carex sterilis, Lobelia kalmii, Muhlenbergia glomerata, Parnassia glauca, Rhynchospora capillacea, Solidago ohioensis, Viola cucullata, Zigadenus glauca*) regularly occur in southern Michigan's fens (Chapman 1984). Some fen plants (*Cirsium muticum, Liatris spicata*) also grow in lakeplain wet prairies.

Vegetation Conversion to Reed Canary Grass. When annual burning ceased, Michigan's wet prairies persisted longer than upland prairies. They were cut for hay, which minimally affected original species abundance and diversity while discouraging invasion by trees and shrubs.

Agricultural practices are known to alter wet prairie (Curtis 1959). The main alteration was due to invasion and replacement of wet prairie plants by reed canary grass (*Phalaris arundinacea*). Although it is considered a native plant, Eurasian strains introduced for agriculture may exist in Michigan (Voss 1972); they were bred to improve early- and late-season forage production, which may increase invasive qualities and ability to displace native plants (Apfelbaum & Sams 1987; Merigliano & Lesica 1998). Grazing facilitated this conversion: Curtis (1959) observed replacement of wet prairie by reed canary grass, Kentucky bluegrass (*Poa pratensis*), and redtop (*Agrostis gigantea*) within three years after the introduction of grazing.

Farmers also dug ditches and installed drain tiles in wet prairies to lower the water table. Such drainage allowed earlier mowing for hay and minimized the risk of farm equipment becoming mired. Kercher et al. (2004) concluded that reed canary grass invasion of wet meadows is accelerated by disruption of hydrology. Michigan's wet prairies also experience increased flooding and drying in agricultural regions. Upland cropland produces surface runoff which floods wet prairies more frequently than before cultivation, but between storms the soil of wet prairies becomes drier due to drainage and diminished groundwater recharge in surrounding cropland. Drainage also stimulates the growth of woody plants (Curtis 1959). When wet prairies of Michigan and nearby states were drained, they were rapidly colonized by willows, aspen, and other woody plants (Davis 1908; Rogers 1966; Anderson 1971).

Lastly, runoff from cropland and urban areas carries sediment (to which phosphorus is attached) and nitrogen (from fertilizers and manure spread on fields). Inputs of sediment, phophorus, and nitrogen encourage the growth of reed canary grass (Perry et al. 2004).

As long as haying occurred, shrubs and trees did not invade these water-starved wet prairies of southern Michigan. After 1950, however, haying largely ceased and forest succession progressed rapidly. Where grazing was practiced, forest succession was delayed, but eventually prairie grasses and forbs were eliminated by reed canary grass invasion.

Lakeplain Wet Prairie

This prairie type has a limited continental range but is easily recognized by its unique combination of species and setting on glacial lake plains, often with mesic sand prairie (Hayes 1964; White and Madany 1981; Chapman 1984). A large area of Michigan's lakeplain wet prairie remained intact in 1900 in Bay and Tuscola Counties, 70 years after the upland prairies were first broken (Figure 16). These last large wet prairies were nearly destroyed in 1880–1910 by immense steam dredges deployed to create farmland out of marshes and wet prairies near Saginaw Bay.

> Among the great enterprises originating in Bay county, is one not known anywhere else in the whole State, of the same kind, known as the Miller and Daglish reclamation of the Saginaw marshes, located partly in Bay and Saginaw counties. This is one of Judge Albert Miller's pets, and consists in the drainage by dredging with a steam dredge around some 1,000 acres of marsh, much of which was under water, making the land fully susceptible of raising grain or grass, and all this was done at much less cost than to clear any timber land, leaving the land completely cleared without stumps. The land is kept clear of water by a small steam engine run at occasional times, at very small cost (Partridge 1881).

The prairies of Saginaw Bay and their destruction were documented by Davis (1898, 1908). Other lakeplain wet prairies were studied by Anderson (1971) and Tryon and Easterly (1975) in Ohio, or noted by settlers and surveyors in southeastern Michigan (Anderson 1819; Hubbard 1838; Farmer 1848; Farmer 1890; Everett 1959). Foerste (1882) found several species of lakeplain wet prairie on the banks of Belle Isle in the Detroit River, including *Platanthera leucophaea*, a federally-endangered orchid (Figure 17). At the time, excursionists gathered the orchids for wildflower bouquets.

FIGURE 16. *Solidago ohiensis* in a lakeplain wet-mesic prairie, Huron County. This plant grows in Great Lakes interdunal wetlands, prairie fens, and prairies where soil pH is also alkaline; several other lakeplain prairie species have a similar distribution in Michigan. Michigan's lakeplain prairies preserve the expansive vistas once seen in upland prairies such as Prairie Ronde in Kalamazoo County. (Photo by Kim Chapman.)

FIGURE 17. *Platanthera leucophaea*, the state and federal endangered prairie white fringed orchid, is an indicator of lakeplain wet-mesic prairie, growing here with *Iris virginica* in Bay County. (Photo by Kim Chapman.)

The dominant plants of lakeplain wet prairie are *Calamagrostis canadensis, Carex aquatilis, C. lanuginosa*, along with lesser amounts of *Andropogon gerardii, Schizachyrium scoparium, Panicum virgatum, Sorghastrum nutans*, and *Spartina pectinata*. Faber-Langendoen and Maycock (1987) described a similar community on Walpole Island, Canada. Their prairie classification at this location also included wet-mesic prairie. Wet-mesic prairie probably exists on Michigan's lakeplains at the lower slopes of sand ridges and on broad flats between wet and mesic sites. Faber-Langendoen and Maycock's wet-mesic prairie contains indicators (Appendix 2) of both mesic sand prairie (e.g., *Quercus palustris, Lobelia spicata, Equisetum arvense, Muhlenbergia mexicana, Krigia biflora*) and of lakeplain wet prairie (e.g., *Liatris spicata, Aster dumosus, Prenanthes racemosa, Asclepias incarnata, Stachys tenuifolia, Potentilla anserina*).

Dolomitic limestone, limestone bedrock, and gravel derived from these materials dominate much of the Great Lake's shoreline of Lower Michigan or are present in submerged reefs. Over the past 10,000 years this material has been ground to sand by waves and ice and this sand forms much of the shore and dune

sand of Lakes Michigan, Huron, and Erie where lakeplain wet prairie is found. The high calcium and magnesium carbonate content of this lake sand elevates the soil pH along coasts and on lakeplains (Voss 1972). Calcareous soils are not present on sand ridges of the lakeplain (where mesic sand prairie occurs) because precipitation has leached the carbonates from the organic-poor sands of the ridges. The alkaline soil and proximity to the shoreline also facilitates colonization of lakeplain wet prairie by species of interdunal wetlands and calcareous fens (e.g., *Carex buxbaumii, Solidago ohioensis, Hypericum kalmii, Potentilla fruticosa*).

CONSERVATION APPLICATIONS

Michigan's prairies and savannas are a diverse, distinctive, and unique element in the continental expanse of tallgrass prairie and savanna. Given the loss of 99.9% of approximately 930,000 ha (2.23 million ac) of Michigan prairie and savanna, every remnant should be preserved and expanded.

The rarity of oak savanna is remarkable because it once defined the character of much of southern Lower Michigan. It is endangered not just in Michigan but throughout eastern North America (Nuzzo 1986; Noss 1995). It should be the priority of every natural resource professional, public land manager, and environmental policy-maker to identify large expanses of potential savanna and begin restoring an open oak canopy and understory. Chances for success will be highest in the historical oak savanna regions where prairie and savanna indicator plants are seen at edges of oak forests. Oak savanna restoration would benefit not just plants, but several declining bird species that preferentially use brushland and open woodland (e.g., Yellow-shafted Flicker, Golden-winged Warbler, Brown Thrasher, Yellow-breasted Chat, Red-headed Woodpecker, Eastern Kingbird, and perhaps Black-billed Cuckoo) (Chapman and Reich 2007). Other wildlife would benefit, including the majority of southern Michigan's butterfly species which need abundant flowering plants and partial shade in the growing season, a condition to be found in high quality oak savanna.

Our understanding of Michigan's prairies and savannas leads us to conclude that landscape scale restoration is needed. Savanna was the landscape matrix in which prairie and other southern Michigan communities were embedded. The dynamics of canopy closure and re-opening depended in large part on landscape scale fire interacting with site factors and long climatic trends, especially drought. Out of this dynamic emerged local variation in plant and animal species distribution and abundance as modified by microsite factors of soil, water table, slope, and aspect. Catastrophic disturbance created both prairie and savanna, and frequent disturbance maintained them in a region where climate favored forest over grassland and savanna. We also must remember that large continuous forests penetrated and surrounded Michigan's savanna landscapes, and still do. These forests were also cleared for agriculture, grazed, and now experience fragmentation due to development. Southern Lower Michigan's large forest remnants support animal species which decline as forests are reduced in size and iso-

lated from one another. Clearly important forest locations must be considered when selecting sites for savanna restoration.

Oak savanna restoration must begin with larger management units than are customary in southern Michigan: 40–160 acres and larger should be the starting size. The approach and outcomes described by Stritch (1990) and Chapman et al. (1995) provide technical guidance. Reducing woody plant dominance is the most important goal in savanna restoration, and fire is the most cost-effective and ecologically appropriate tool to achieve this goal.

There is much resistance to using fire in Michigan's forests. It is considered unnatural, harmful to forest development, and problematic due to technical difficulties and a lack of experience. Our research provides ample evidence that, in fact, removing fire from Michigan's landscape has altered in a brief period the landscape that persisted over southern Lower Michigan for thousands of years and varied only at local scales of distribution and abundance in response to climate and disturbance. Ironically a preservationist mentality in Michigan's conservation community has perpetuated the negative impact of European settlement on savanna and prairie. If Michigan's conservation community wishes to have prairies and savannas, it should be open to the destruction of certain forest canopies, aware of the role that oak resprouts play in Michigan's ecology, and dedicated to frequent burning of fire-adapted communities—every year initially, then perhaps every other year once tree canopy cover falls below 50%. Eventually large savanna landscapes will be created which would, we believe, resist invasion by light-seeded early-successional trees (e.g., green ash, box-elder, elm) and non-native invasive shrubs (e.g., Tatarian honeysuckle) due to their widespread suppression by fire, and contain a range of tree canopy cover and light conditions which could support the potential species diversity of Michigan's savanna regions. There is considerable evidence that disturbance, rather than lack of disturbance, tends to maintain ecological stability and diversity over time (Pickett and White 1985). This is especially true of fire-adapted communities like prairie and savanna.

Reintroducing fire over large areas in southern Michigan will have unknown outcomes at a detailed level but at a broad level outcomes are generally known. Fire across large areas will result in greater heterogeneity of vegetation patches and a greater variety of plant and animal life compared to that found in small savanna and prairie remnants. The long time scale of savanna vegetation dynamics is encouraging: 170 years of fire suppression may not be too long to recover many features and ecological processes of savanna in southern Lower Michigan. The best candidates for restoration are large public lands to which can be added large private conservation lands in former oak openings and prairie regions. Marginal cropland on poor soils and abandoned hay meadows and pastures in savanna regions sometimes are colonized by prairie and savanna plants. These are good candidates for restoration if also adjacent to oak forest which was formerly savanna.

We support recent state and federal efforts toward restoring warm-season grasses and savanna in Michigan. Wherever possible, however, we encourage a gradual aproach that draws upon available biodiversity stores, such as existing patches containing appropriate prairie/savanna herbs, as well as seed banks and other cryptic stores that may be brought to light by fire. More drastic efforts, such

as plowing and planting, should not be pursued until a thorough biological inventory has demonstrated an absence of existing appropriate flora. Adaptive management principles are clearly needed: goals for outcomes are checked against actual outcomes measured in restoration areas, and changes in management practices are implemented if the goals are not being achieved (e.g., Nyberg 1999).

An alternative to restoring savanna with fire on public forestland is to plant prairie on cropland, then plant oak seedlings in the established prairie. Since most cropland is privately owned, it would need to be purchased. Non-tiled, non-irrigated cropland in southern Lower Michigan is priced at $2000–$4000 per acre (Wittenberg and Harsh 2006). A one-time prairie planting would cost $1500–$5000 per acre, followed by 2–3 years of weed management (mowing and herbiciding) at $1500–$3500 /acre/year. Thereafter prescribed burning could be employed at a cost of $500–$1000/acre/year. Planting is best done on poorer soils because of the large number of aggressive agricultural weeds adapted to heavy soils. By contrast, restoration on public forestland would entail one-time costs of preparing a site for a prescribed burn (e.g., installing fire breaks) and carrying out the burning ($500–$1000/acre/year). Once established, oak seedlings could be planted at a cost of $300–$1000/acre depending on seedling size. A significant challenge in this approach is how to protect the oak seedlings while managing the prairie with fire or other means. In short, the public forestland restoration choice is cheaper and would give faster results than planting cropland with prairie and oak seedlings.

Michigan's distinct combination of extensive savanna with embedded upland and wet prairies differs from the prairie-savanna conditions of states farther west. Large-scale conservation of Michigan's prairies and savannas will preserve a unique ecological landscape and re-create an interesting and beautiful setting for scientific study and the enjoyment of Michigan's citizenry.

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APPENDIX 1. Presence (%) of species in Michigan prairie and savanna plant communities. Species with >50% presence or high indicator ranking are reported. For a full species list see Chapman (1984).

	DSPB[1]	MSP	OOH	OO	MP	WP	LWP
Species							
Achillea millefolium var. occidentalis		100		69	75		60
Agrostis hyemalis		50					
Aletris farinosa		67					
Allium canadense						83	60
Ambrosia artemisiifolia	67						
Ambrosia psilostachya	50						
Amorpha canescens				<50			
Amphicarpa bracteata						50	
Andropogon gerardii	83	83	67	92	100	50	100
Anemone canadensis						50	60
Anemone cylindrica	67	67	83	92	75		
Anemone virginiana						83	
Angelica atropurpurea						50	
Antennaria parlinii	83	50	67	69	50		
Apios americana						100	
Apocynum androsaemifolium	67	83			75	67	
Apocynum cannabinum	50					50	100
Arabis glabra	50						
Arabis lyrata	50						
Aristida purpurascens	50						
Artemisia campestris	83						
Asclepias amplexicaulis	50						
Asclepias incarnata							60
Asclepias sullivantii							60
Asclepias syriaca	67			54	50	67	60
Asclepias tuberosa	83	83	50	100	75		
Asclepias verticillata	67						
Aster dumosus							80
Aster ericoides		50					100
Aster laevis		50		85	75	50	
Aster lanceolatus						67	
Aster novae-angliae						100	80
Aster oolentangiensis	83	50	50	69	50		
Aster pilosus				69			
Baptisia lactea					<50		
Baptisia tinctoria		50					
Besseya bullii			50				
Blephilia ciliata	50						
Bouteloua curtipendula			<50				
Bromus ciliatus						50	
Cacalia atriplicifolia					50		
Calamagrostis canadensis						83	100
Calystegia sepium						50	80
Campanula rotundifolia			67				
Carex bebbii						67	
Carex bicknellii					50		
Carex buxbaumii							60
Carex pensylvanica	100	50	50	54			
Carex stricta						50	
Carya glabra			67				

APPENDIX 1. Continued.

	DSPB[1]	MSP	OOH	OO	MP	WP	LWP
Ceanothus americanus	100		67	69	100		
Cicuta maculata						83	60
Cirsium discolor							60
Cirsium muticum							60
Comandra richardsiana	67	50	83	77	75	50	100
Coreopsis palmata					75		
Coreopsis tripteris	50	100	50		100	50	
Cornus florida			50				
Cyperus filiculmis	100						
Dalea purpureum					<50		
Danthonia spicata	83	67					
Desmodium canadense		83		54		83	80
Desmodium canescens					<50		
Desmodium illinoense				54	50		
Desmodium marilandicum	50			62			
Desmodium sessilifolium				<50	<50		
Dioscorea villosa					75		
Echinacea purpurea					<50		
Eleocharis elliptica							100
Equisetum arvense		67				67	60
Equisetum hyemale							
Equisetum laevigatum		67			50		
Erigeron annuus					50		
Erigeron philadelphicus							80
Erigeron strigosus	67	67		85	50		
Eryngium yuccifolium					50		
Eupatorium maculatum						67	
Euphorbia corollata	100	67	67	92	75		
Euthamia graminifolia		83			75	100	60
Fragaria virginiana	100	100		85	75	83	100
Frasera caroliniensis					50		
Galium boreale			67		100	83	
Galium pilosum	50				50		
Galium trifidum							80
Gentiana alba					50		
Gentiana andrewsii						100	60
Geranium maculatum					75	50	
Gnaphalium obtusifolium	67						
Hedeoma pulegioides				<50	<50		
Helianthemum canadense	83	50			50		
Helianthus divaricatus	50		67		50		
Helianthus giganteus						83	
Helianthus occidentalis	67			69	75		
Helianthus pauciflorus					<50		
Helianthus strumosus					75		
Heliopsis helianthoides					<50		
Hepatica americana			<50				
Heuchera americana var. hirsuticaulis		50			75		
Hieraceum gronovii	67						
Hieraceum longipilum	100			54			
Houstonia longifolia			<50				
Hypoxis hirsuta						50	
Iris virginica						67	60
Juncus balticus							100
Juncus tenuis		67					

APPENDIX 1. Continued.

	DSPB[1]	MSP	OOH	OO	MP	WP	LWP
Juniperus virginiana			67				
Krigia biflora		50					
Krigia virginica	67						
Kuhnia eupatorioides					50		
Lactuca canadensis	100	50		77	100		
Lathyrus palustris						50	80
Lechea villosa		50					
Leersia oryzoides							
Lespedeza capitata	67	83	50	77	75		
Lespedeza hirta	50		50		75		
Liatris aspera	83						
Liatris cylindracea	50						
Liatris spicata		67					100
Linaria canadensis	50						
Lithospermum canescens				54	75		
Lithospermum caroliniense	67						
Lobelia spicata		50					
Lupinus perennis	83						
Luzula multiflora		50			75		
Lycopus americanus						50	80
Lysimachia ciliata						50	
Lysimachia quadriflora							100
Lythrum alatum							60
Monarda fistulosa	67	83	50	77	75	83	80
Monarda punctata	67						
Muhlenbergia mexicana						50	
Oenothera clelandii	50						
Onoclea sensibilis						50	
Oxypolis rigidior						100	
Panicum commonsianum	50						
Panicum depauperatum	50						
Panicum leibergii					<50		
Panicum oligosanthes	83				75		
Panicum virgatum							100
Penstemon hirsutus	50		67				
Phlox bifida			<50				
Phlox pilosa	50	50	67		75		
Phlox subulata			<50				
Pinus strobus			50				
Platanthera leucophaea							60
Polygala polygama	67						
Polygala sanguinea		83					
Polygonatum biflorum	50						
Polygonatum pubescens	50						
Populus grandidentata			50				
Potentilla anserina							60
Potentilla arguta				<50	<50		
Potentilla simplex		67		54	50		
Prenanthes racemosa							80
Prunus serotina			50				
Prunus virginiana	50						
Pteridium aquilinum		67	67		50		
Pycnanthemum virginianum		83				83	80
Quercus alba			83				
Quercus rubra			50				

APPENDIX 1. Continued.

	DSPB[1]	MSP	OOH	OO	MP	WP	LWP
Quercus velutina			100				
Ranunculus fascicularis	50				75		
Ratibida pinnata				69	75	83	
Rhus copallina	<50						
Rhus typhina			50				
Rosa carolina	50		50	77	100		
Rosa palustris							60
Rudbeckia hirta	83	83	67	85	75	50	60
Ruellia humilus					<50		
Salix humilis		67		62	100		
Sassafras albidum			50				
Schizachyrium scoparius	100	100	67	85	100		80
Scirpus validus							60
Scleria triglomerata		50					
Senecio plattensis	50						
Silphium integrifolium					50		
Silphium laciniatum					<50		
Silphium terebinthinaceum					50	67	
Smilacina racemosa			67	54	75		
Smilacina stellata						50	
Solidago altissima					50	83	100
Solidago gigantea						50	
Solidago juncea	83	67		69			
Solidago nemoralis	100	67	67	85	50		80
Solidago ohioensis							100
Solidago riddellii						67	
Solidago rigida		50		54	100	50	
Solidago speciosa	67			62	50		
Sorghastrum nutans	50	67		54	100	67	100
Spartina pectinata					50	83	100
Specularia perfoliata	67						
Spiraea alba		67					
Sporobolus heterolepis					<50		
Stachys tenuifolia							100
Stipa avenacea	<50						
Stipa spartea			67				
Taenidia integerrima					75		
Tephrosia virginiana	50						
Thalictrum dasycarpum					100	100	
Thelypteris palustris						100	
Tradescantia ohiensis	83		67	77	100		
Trichostema dichotomum	<50						
Verbena stricta					75		
Vernonia missurica							80
Veronicastrum virginicum		50			100	83	60
Vicia americana					50		
Viola pedata	50		50				
Viola pedatifida					<50		
Viola sagittata		67					
Viola sororia					50		
Vitis aestivalis			83				
Ziza aurea					75	67	60

[1]DSPB = Dry sand prairie/barrens; MSP = Mesic sand prairie; OOH = Oak openings on hillsides; OO = Oak openings; MP = Mesic prairie; WP = Wet prairie; LWP = Lakeplain wet prairie

APPENDIX 2. Predictive levels of indicator species in Michigan prairie and savanna plant communities (see Methods, p. 9).

High	Medium-High	Medium	Medium-Low	Low
DRY SAND PRAIRIE & OAK BARRENS				
Artemisia caudata	Ambrosia psilostachya	Polytrichum piliferum	Cyperus filiculmis	Ambrosia artemisiifolia
	Arabis glabra	Rhus copallina	Liatris aspera	Asclepias amplexicaulis
	Arabis lyrata	Stipa avenacea	Lupinus perennis	Hieraceum gronovii
	Asclepias verticillata	Trichostema dichotomum		Liatris cylindracea
	Blephilia ciliata			Lithospermum caroliniensis
	Cladonia spp.			Monarda punctata
	Gnaphalium obtusifolium			Panicum depauperatum
	Krigia virginica			Polygala polygama
	Linaria canadensis			Polygonatum biflorum
	Oenothera rhombipetala			Prunus virginiana
	Panicum commonsianum			Senecio plattensis
	Polygonatum pubescens			Tephrosia virginiana
	Specularia perfoliata			
MESIC SAND PRAIRIE				
	Baptisia tinctoria	Polytrichum juniperinum	Agrostis hyemalis	Acer rubrum
	Juncus tenuis	Solidago rugosa	Aster ericoides	Aletris farinosa
	Lechea villosa		Krigia biflora	Equisetum arvense
	Polygala sanguinea		Lobelia spicata	Liatris spicata
	Spriraea alba		Populus tremuloides	Quercus palustris
			Pycnanthemum virginianum	Scleria triglomerata
				Viola sagittata
OAK OPENINGS (HILLSIDES)[1]				
Vitis aestivalis	Besseya bullii	Amelanchier arborea	Quercus rubra	
	Campanula rotundifolia	Bouteloua curtipendula		
	Cornus florida	Hepatica americana		
	Pinus strobus	Houstonia longifolia		
	Populus grandidentata	Phlox bifida		
	Stipa spartea	Phlox subulata		
OAK OPENINGS[2]				
	Aster pilosus			
MESIC PRAIRIE				
Helianthus strumosus	Gentiana flavida	Viola pedatifida	Coreopsis palmata	Cacalia atriplicifolia
	Frasera caroliniensis		Dioscorea villosa	Erigeron annuus
	Vicia americana		Geranium maculatum	Eryngium yuccifolium

MESIC PRAIRIE (continued)			
	Viola sororia	Poa pratensis	Kuhnia eupatorioides
		Rhus glabra	Quercus macrocarpa
		Taenidia integerrima	Rubus hispidus
		Thalictrum dasycarpum	Silphium integrifolium
		Verbena stricta	Silphium terebinthinaceum
		Zizia aurea	Solidago altissima
			Spartina pectinata
WET PRAIRIE			
Apios americana	Amphicarpa bracteata	Anemone virginiana	Eupatorium maculatum
Oxypolis rigidior	Angelica atropurpurea	Galium boreale	Onoclea sensibilis
Saxifraga pensylvanica	Aster simplex	Helianthus giganteus	
Thelypteris palustris	Bromus ciliatus	Ratibida pinnata	
	Carex bebbii	Thalictrum dasycarpum	
	Hypoxis hirsuta		
	Lysimachia ciliata		
	Muhlenbergia mexicana		
	Phalaris arundinacea		
	Salix interior		
	Smilacina stellata		
	Solidago gigantea		
	Solidago riddellii		
LAKEPLAIN WET PRAIRIE			
Aster dumosus	Asclepias incarnata	Andropogon scoparius	
Eleocharis elliptica	Asclepias sullivantii	Aster ericoides	
Galium trifidum	Carex buxbaumii	Erigeron philadelphicus	
Lysimachia quadriflora	Cirsium muticum	Liatris spicata	
Populus deltoides	Fraxinus pensylvanica	Panicum virgatum	
Prenanthes racemosa	Lythrum alatum	Poa compressa	
Solidago ohioensis	Platanthera leucophaea	Solidago nemoralis	
Stachys tenuifolia	Potentilla anserina		
Vernonia missurica	Rosa palustris		
	Scirpus validus		

"[1]Comandra richardsiana, Penstemon hirsutus, and Quercus alba reached maximum presence in Oak Openings (Hillsides) but occurred in <50% of stands of this plant community."

"[2]Amorpha canescens, Anemone cylindrica, Asclepias tuberosa, Aster laevis, and Erigeron strigosus reached maximum presence in Oak Openings but occurred in <50% of stands of this plant community."

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3. Letters to the Editor can be formatted as general text without the specific sections listed above. However, literature cited and any tables or figures should be formatted as described below.

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Prairie and Savanna in Southern Lower Michigan:
History, Classification, Ecology
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On the cover: *A dry sand prairie in Newaygo County, at the dry end of the prairie soil moisture gradient. These prairies are often located in broad depressions surrounded by former oak barrens and oak-pine barrens which now are closed-canopy woodlands due to 100 years of fire suppression. (Photo by Mike Kost.)*

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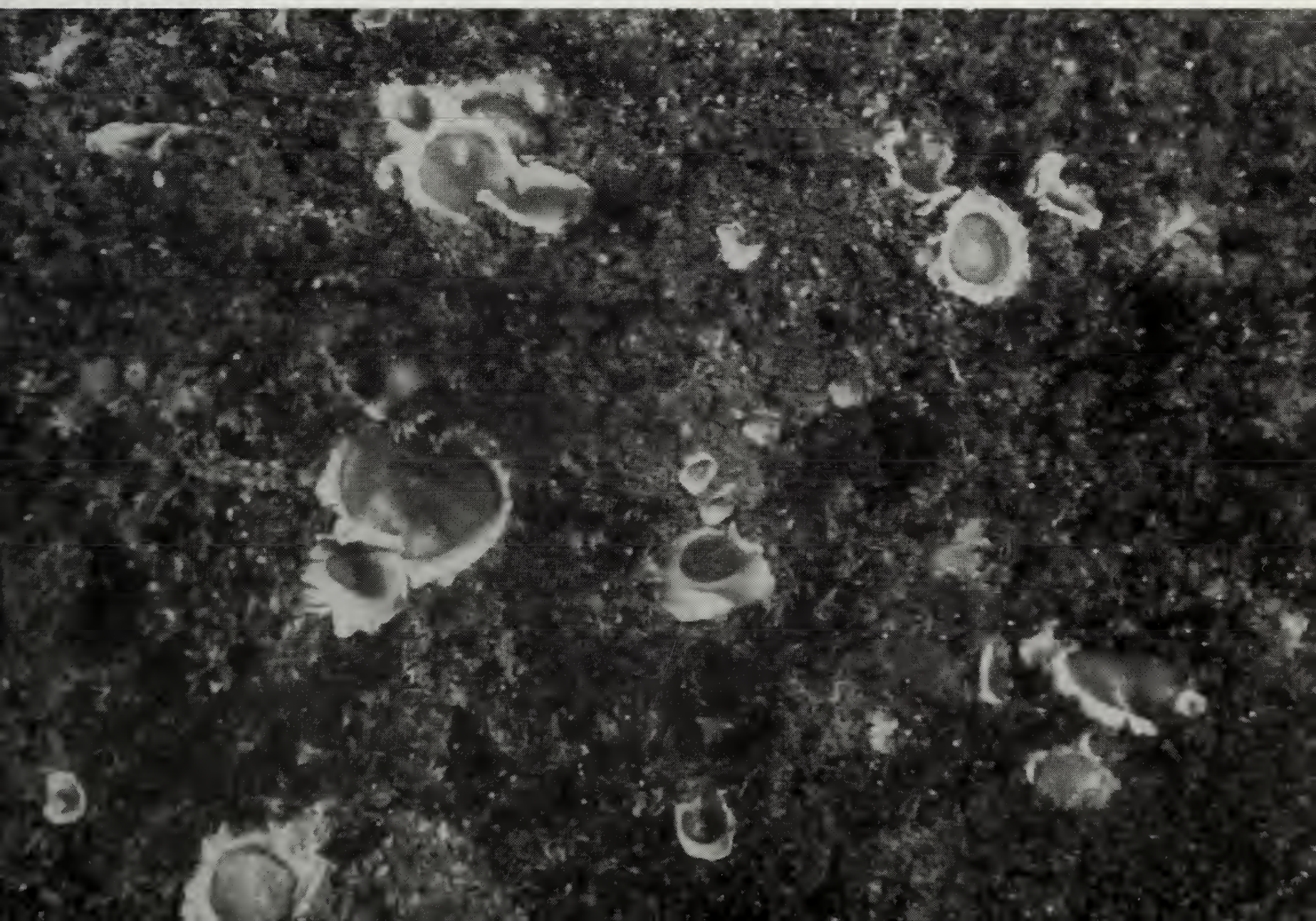

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THE WESTERN GIANT PUFFBALL (*CALVATIA BOONIANA* A. H. SMITH) IN NORTHERN MICHIGAN

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ABSTRACT

Collections of the western giant puffball, *Calvatia booniana* A. H. Smith, are described from the Upper Peninsula of Michigan. Two collections were made by the authors in Houghton Co. in 2006 and 2007, and one collection, housed in the University of Michigan Fungus Collection, was made in Marquette Co. in 1968 by Ms. Ingrid Bartelli, and identified by Dr. Alexander H. Smith of the University of Michigan. Dr. Smith originally named the species based on collections from Idaho and Oregon, generally associated with sagebrush (*Artemesia* spp.). However, the collections from Houghton Co. were associated with white cedar (*Thuja occidentalis*). A survey of several other fungus herbaria yielded no other collection of *C. booniana* in the eastern U.S. Collections were studied macroscopically and microscopically and compared to the eastern giant puffball, *Calvatia gigantea* (Batsch *ex.* Pers.) Lloyd, to which it is quite similar. Because of the visibility and popularity of these mushrooms, a brief review of the history, naming and occurrence of these species is provided.

INTRODUCTION

The giant puffball is one of the most magnificent examples of massive spore production by any organism; a single specimen may produce upwards of eight trillion spores (Richter and Beardslee 2004). The fungus is a saprotrophic decayer of cellulosic plant materials (Richter and Bruhn 1989) that produces its fruiting bodies on the ground. Large white fruiting bodies, some up to two feet across, are common in late summer and fall in northern Michigan. Forever amazed by the size of these mushrooms, our forest pathology laboratory enthusiastically accepts huge specimens and receives numerous reports of basidiocarps that appear like volley balls in yards and waysides every summer and fall.

Calvatia gigantea (Batsch ex. Pers.) Lloyd (Figure 1) occurs throughout eastern North America (Miller and Miller 2006) and Europe (Breitenbach and Kranzlin 1986). This puffball has been known to science by at least nine other names throughout its history (Zeller and Smith 1964), and for many years the name *Langermannia gigantea* was applied. However, for reasons beyond the scope of this note, the name *Calvatia gigantea* has been conserved and is currently correct for this organism (Hawksworth *et al.* 1995).

In the western United States a different species of giant puffball occurs, *Calvatia booniana* A.H. Smith. The western giant puffball attains the size of *C. gi-*

FIGURE 1. *Calvatia gigantea*, the eastern giant puffball. This specimen found Sept. 23, 2007 in a grassy field in northern Marquette Co., Michigan, measuring approximately 30 × 20 × 20 cm (not collected).

gantea, and is also white, however, it is distinguished by having a sculptured surface of plates and ridges not unlike the back of a tortoise (Smith 1975). It was described as a new species in 1964 by the renowned University of Michigan mycologist, Dr. Alexander H. Smith (Zeller and Smith 1964). In this treatment of the genus *Calvatia* in North America Dr. Smith writes about *C. booniana*:

> "This species has been misidentified for the last fifty years as *C. gigantea,* no doubt because of its large size. Dr. Wm. Judson Boone, the first president of the College of Idaho, who was keenly interested in the central Rocky Mountain mushroom flora, had some beautiful mushroom specimens which I saw in 1935. Hence, I take pleasure in dedicating this species to him."

Arora (1986) treats both the eastern giant puffball (*C. gigantea*) and the western giant puffball (*C. booniana*). In addition, he considers the west coast form of *C. gigantea* to be different than the *C. gigantea* found in eastern North America and Europe, as the surface of the former is scaly rather than perfectly smooth like the latter. He considers the true identity of the west coast giant puffball a "minor mystery," and separate from *C. booniana* (Arora 1986).

The western giant puffball is considered equal in edibility to the eastern giant puffball, to which we can attest. Perhaps one of the differences between the two is the strong odor of the western giant puffball, which becomes quite foul upon

drying, and is mentioned by Lincoff (1981). Although we have also detected foul odors emitted by the eastern giant puffball with age and drying.

METHODS

Fruiting bodies of giant puffballs were collected, measured, photographed and their macroscopic characters described. In the laboratory, spores and glebal hyphae of mature fruiting bodies were mounted in 5% KOH and observed at 400X using a Nikon Optiphot® microscope. For each microscopic character (spores or capillitia), ten measurements were made of mature elements selected at random on the slide and the size range reported. Specimens were air-dried and retained in the collection of the first author at Michigan Technological University for eventual deposit in the University of Michigan Herbarium Fungus Collection. The single specimen obtained from the University of Michigan Herbarium Fungus Collection (MICH) was examined similarly to those collected by the authors.

RESULTS

Field Collections

On July 11, 2006 a large white puffball (DR06-001) was found in a yard in Hancock (Houghton Co.), Michigan (Figure 2) along a row of white cedars (*Thuja occidentalis*). The basidiocarp measured approx. 30 × 20 × 16 cm, and

FIGURE 2. *Calvatia booniana*, the western giant puffball (DR06-001), found July 11, 2006 in a yard in Hancock (Houghton Co.), Michigan under a row of cedar trees, measuring approximately 30 × 20 × 16 cm.

was characterized by having a surface of polygonal knobs and plates approx. 2–3 cm diam., with a thick cord-like rhizomorph attached to the base. Based on these characters we tentatively identified the specimen as the western giant puffball, *C. booniana*.

Comparisons of the mushroom collected in Hancock, Michigan to published descriptions was difficult, as it is not covered in the better-known guides for eastern North America. Lincoff (1981) illustrates and compares both the eastern and western giant puffball, and the mushroom found clearly fit the description of the western giant puffball based on size and peridium surface. Interestingly, but unlike our collections, wherever it is discussed, the western giant puffball is considered a feature of sagebrush areas (*Artemesia* spp.) of the western United States (Miller and Miller 2006, Smith and Smith-Weber 2001, Smith 1975, Zeller and Smith 1964).

If one delves further into the definitive work on the Calvatias in North America by Zeller and Smith (1964), comparing the description of the eastern giant puffball with the western giant puffball, one finds that there are only slight differences in the microscopic characters. The differences could easily be within the range of variability of the structures described – approximately a micrometer (μm) or less—and one would not be able to separate the two species based on spores or capillitia alone. Spores of *C. gigantea* range from 3.3–5.5 × 3.0–5.0 μm, while spores of *C. booniana* range from 3.9–6.0 × 3.3–5.5 μm. Capillitial hyphae of *C. gigantea* range from 2.2–8.8 μm, compared to 3.3–8.8 μm for *C. booniana*, and both species' spores are smooth to finely spiny (Zeller and Smith 1964). The principal morphological difference between these two giant puffballs is in the appearance of the outer peridium – sculptured and plated in the western and smooth in the eastern (Zeller and Smith 1964).

We studied the spores and capillitial hyphae of the collection (DR06-001) that, based on macroscopic characters, was tentatively identified as *C. booniana*. The smooth to finely spiny spores measured 4.5–6.0 × 3.5–5.5 μm, while the diameter of capillitial hyphae measured 3.5–7.5 μm. Therefore, spore shape and size, and size of capillitial hyphae are within the range of that described for *C. booniana*.

In September 2007 we went back to the yard where the western giant puffball fruited in 2006 and found eight maturing fruiting bodies of *C. booniana* (DR07-010) measuring 15 to 30 cm diam., all within approximately 3 m of each other (Figure 3). Remarkably, within a few feet of the western giant puffballs, were six fruiting bodies of the eastern giant puffball, *C. gigantea* (DR07-011) equal in size, but contrasting in appearance with their smooth peridium (Figure 4). Because we visited late in the season, the puffballs had matured and were already turning brown. The sculptured surface of the western giant puffball was broken into distinct separated plates, while the eastern giant puffball was smooth.

Herbarium Collections

The University of Michigan Herbarium Fungus Collection (MICH) holds 290,000 specimens of fungi (see http://herbarium.lsa.umich.edu/index2.html), including 34 collections of *C. booniana*. The MICH collections include the type specimen from Oregon (AHS 65191), upon which the species is described, for

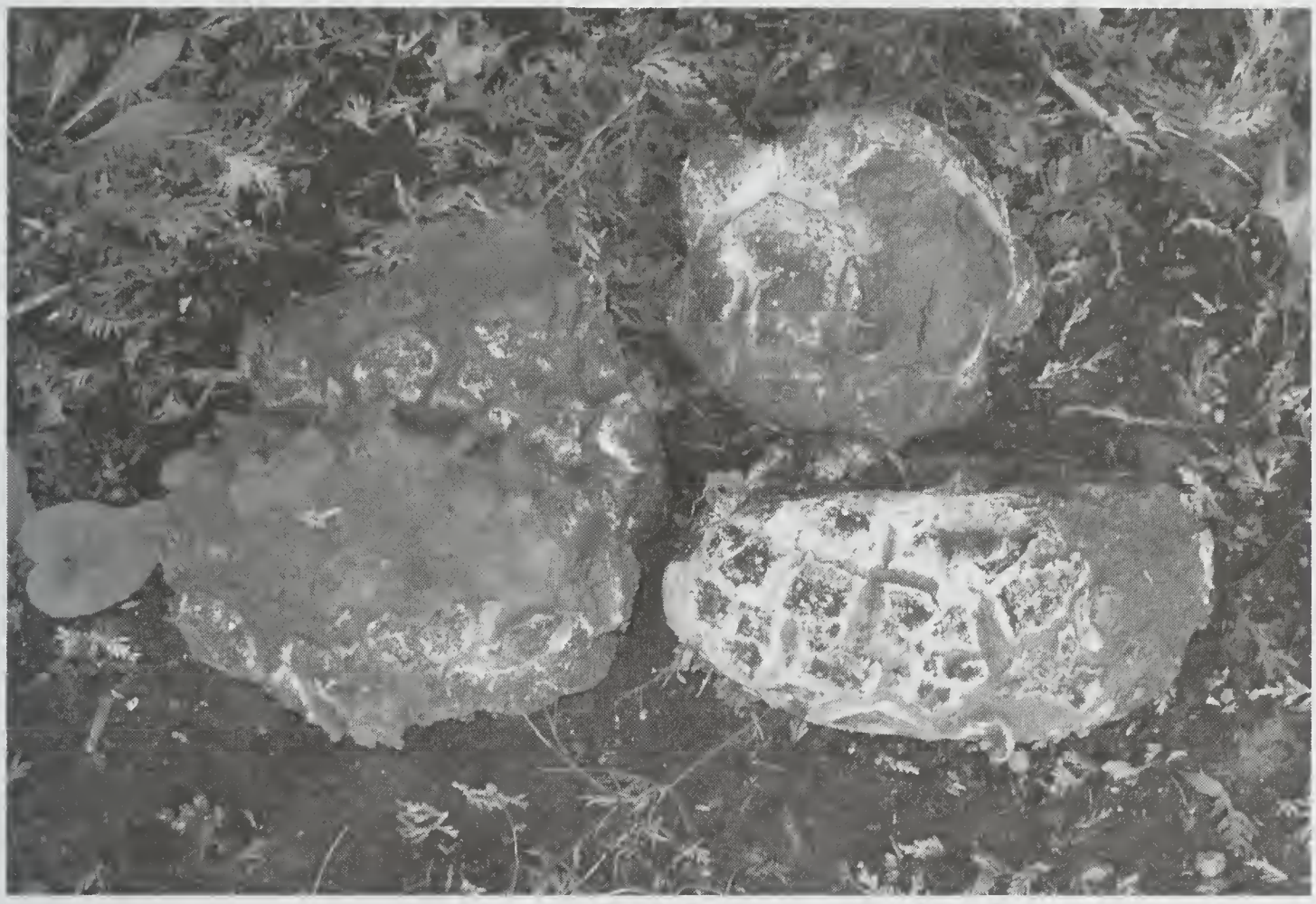

FIGURE 3. Three mature specimens of *Calvatia booniana*, the western giant puffball (DR07-010), found Sept. 27, 2007 in the yard in Hancock, Michigan where the younger specimen fruited in July 2006 (Fig. 2); eight maturing fruiting bodies were found measuring 15 to 30 cm diameter, all within the space of approximately 3 m of each other.

FIGURE 4. Mature specimens of *Calvatia gigantea*, the eastern giant puffball (DR07-011), measuring 20 to 30 cm diam., found in the same yard in Hancock, Michigan as the western giant puffball on Sept. 27, 2007.

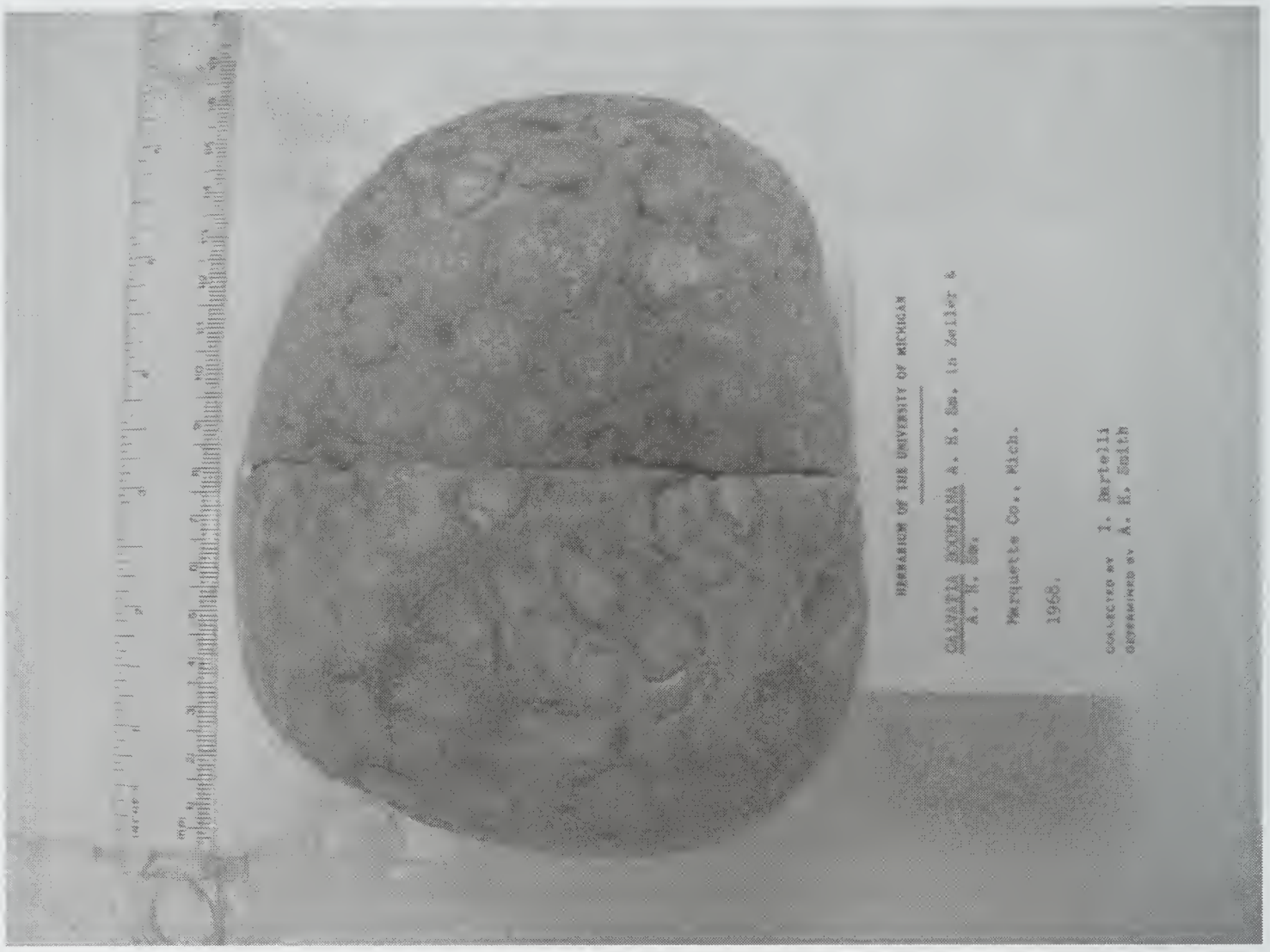
HERBARIUM OF THE UNIVERSITY OF MICHIGAN
Calvatia booniana A. H. Sm. in Zeller &
A. H. Sm.
Marquette Co., Mich.
1968.
collected by I. Bartelli
determined by A. H. Smith

FIGURE 5. *Calvatia booniana*, the western giant puffball (IB 1968-7431) from the University of Michigan Herbarium (MICH), collected in Marquette Co., MI. 1968 (no month, date or habitat recorded); specimen measures approximately 16 × 13 × 11 cm.

which there is a nice picture that matches our mature specimens well. Thirty-three of these collections are from the western U.S. (24 from Idaho, three from Arizona, two from Colorado, two from New Mexico, and one each from Oregon and Utah). However, one collection (IB 1968-7431) is from Marquette Co., Michigan, also in the Upper Peninsula, less than 100 miles east of Houghton Co. where the authors collected in 2006 and 2007.

The MICH herbarium collection of *C. booniana* from Marquette was made in 1968. It was deposited by Ms. Ingrid Bartelli, a respected field mycologist who collected and authored papers with Dr. Smith, and who also authored a series of pamphlets on Michigan mushrooms that were in popular use for many years. Ms. Bartelli was certainly familiar with the common eastern giant puffball, as it is illustrated in one of her pamphlets (Bartelli 1979). Furthermore, of the 31 collections of *C. gigantea* in MICH, one is deposited by her, also in 1968 from Marquette Co., but with scant collection data provided, except "near Marquette," to indicate the city with the same name.

The MICH collection of *C. booniana* of Ms. Bartelli was requested by the authors for examination (Figure 5). The fruitbody measures approximately 16 × 13 × 11 cm, somewhat smaller than the collection made in Hancock, MI in 2006; closer in size to the mature specimens found in 2007. The peridium of the specimen from MICH has the characteristic polygonal plates that are distinctive for the western giant puffball, however, the plates are not raised as on the young

specimen found in 2006, suggesting this may be a function of age. It also lacks the cord-like rhizomorph at the base which is characteristic of the species (Zeller and Smith 1964), and which is present on our collections, however, the rhizomorph may have been broken off when collected. The *C. booniana* from MICH was nearly mature, with the gleba just beginning to turn brown. Spores are smooth to minutely spiny, measuring 4.0–5.5 × 3.5–5.5 µm; diameter of capillitial hyphae measured 3.5–7.0 µm. Therefore, spore shape and size and size of capillitial hyphae are within the range of that described for *C. booniana* (Zeller and Smith 1964).

The herbarium card lists Dr. A. H. Smith as the identifier of the MICH specimen of *C. booniana*. Associated with the specimen is a slip of paper with a note, presumably in the hand writing of Dr. Smith, saying, "*Calvatia booniana* Smith Marquette County Mich 1968. Brought in to Mrs. Ingrid Bartelli. *fide AHS*." However, there is no month, date, location, host or habitat information provided for the collection.

An inquiry to the curator of the Willard Sherman Turrell Herbarium Fungus Collection, at the University of Miami, Oxford, Ohio, which holds over 100,000 specimens of fungi, resulted in no specimens of *C. booniana* (Dr. Michael A. Vincent, Curator (personal communication)). A search of the Field Museum of Natural History, Chicago, IL website also resulted in no *C. booniana* collections deposited. Likewise, a search of the Cornell University, Plant Pathology Herbarium, Ithaca, NY website, which holds over 400,000 fungus specimens, also resulted in no collections of *C. booniana*. In addition, of 3,570 species of fungi recorded on the checklist of Wisconsin (Parker 2006), *C. booniana* is not listed among five species of *Calvatia*.

DISCUSSION

The difference in the outward appearance of the eastern and western giant puffballs is striking and apparently one of the most significant characters that separates these two species. Based on the published description of the shape and color of the peridium, spore size and shape, and size of capillitial hyphae, we determined that the specimens found in Hancock, Michigan are indeed *C. booniana*. The other character that separates the eastern from the western giant puffball is habitat: grassy fields and lawns for the former and sagebrush areas for the latter. Thus, it is notable to find the western giant puffball in eastern North America outside of its usual range and habitat.

It is interesting to speculate that our specimens of *C. booniana* might simply be contorted forms of *C. gigantea*, caused by some genetic aberration or infectious agent, or modified by growth under different environmental conditions. Genetic or molecular analysis may be required to determine if *C. gigantea* and *C. booniana* are truly separate species or if they are conspecific. Cultures made from fresh tissue of both the eastern and western giant puffballs were also morphologically indistinguishable. For now, however, based on the published descriptions, it must be concluded that the large, smooth puffballs that we collected

are the eastern giant puffball, *Calvatia gigantea* (Batsch ex. Pers.) Lloyd, and the sculptured fruitbodies of the same size, in the same place, is a rare occurrence of the western giant puffball, *Calvatia booniana* A. H. Smith in eastern North America.

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STUDIES ON MICHIGAN CHRYSOPHYCEAE. VIII. ADDITIONS TO THE FLORA

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ABSTRACT

Four species of silica-scaled golden-brown algae (Synurophyceae) and one non-siliceous scaled taxon of uncertain systematic placement are newly reported for Michigan. One species, *Mallomonas variabilis*, is reported for the first time from the U.S.

KEYWORDS: silica-scaled chrysophytes, *Mallomonas*, Synurophyceae, *Pseudodendromonas*

INTRODUCTION

Algae known as the silica-scaled chrysophytes (belonging to the algal classes Chrysophyceae and Synurophyceae) are characterized by cells possessing an envelope of siliceous scales, sometimes with associated bristles (Nicholls & Wujek 2003; Siver 2003). These algae (or their shed scales) have long been recognized as important indicators of environmental conditions. These chrysophytes are second in importance only after diatoms as indicators of the past ecology of lacustrine environments (Smol 1995; Stoermer 1999). For example, the effects of acid rain on the aquatic environment were demonstrated by examining the species changes of scaled chrysophytes in present and past sediments to demonstrate changes in the environment over time. Identification of scaled chrysophytes is based upon the morphology of scales that often are preserved in sediments. Light microscopy based identifications are of limited value as electron microscopy usually is necessary to distinguish a scale's morphology for species identification.

Previous Michigan studies, while not emphasizing acid rain effect, have centered on the chrysophyte flora, particularly silica-scaled chrysophytes (Wujek & Igoe 1989 and literature therein, Wujek & Thompson 2002; Wujek 2006). In adjacent Indiana Wujek and colleagues (Wujek & Swinehart 1995; Wujek & Bechtel 1997) have also conducted several more in-depth TEM based taxonomic and ecological investigations.

This paper presents observations that have continued since the study of Michigan Chrysophyceae began early in 1972 and is the eighth of the series. I used transmission electron microscopy (TEM) to examine samples collected from eight counties.

TABLE 1. Location of silica-scaled chrysophytes collected May 1987 though June 2006.

Taxon	Location	County	Date
Mallomonas mangofera var. *mangofera*	School Section Lake	Mecosta	4 June 1997
Mallomonas multisetigera	Lake Geneserath, Smith's Bog	Charlevoix, Cheboygan	20 May 2006, 23 May 1987
Mallomonas portae-ferreae var. *reticulata*	Bass Lake	Montcalm	14 Sept. 1987
Mallomonas variabilis	Lake Lansing Lake Skegemog	Ingham Antrim	15 June 1997 20 June 1997
Pseudodendromonas vlkii	Little Tom Lake, Coldwater Lake	Allegan, Isabella	4 May 1986 15 Aug. 1999

METHODS AND MATERIALS

Near shore phytoplankton samples were collected with a plankton net (10 μm mesh size) during the late spring or summer months sporadically from 1986 through 2006 (Table 1). Time of sampling varied during daylight hours. Observations and analysis are as described in Wujek & Hamilton (1972) and Wujek et al. (2006). All identifications were based on TEM.

RESULTS AND DISCUSSION

Four silica scaled chrysophytes not previously reported from Michigan were observed (Table 1; Figs. 1–4). The taxa reported include one new record for the United States, *Mallomonas variabilis*. Non-siliceous scales of the organic scaled chrysophyte-like *Pseudodendromonas vlkii* were also observed (Fig. 5).

Mallomonas mangofera var. *mangofera* Harris & Bradley Fig. 1.

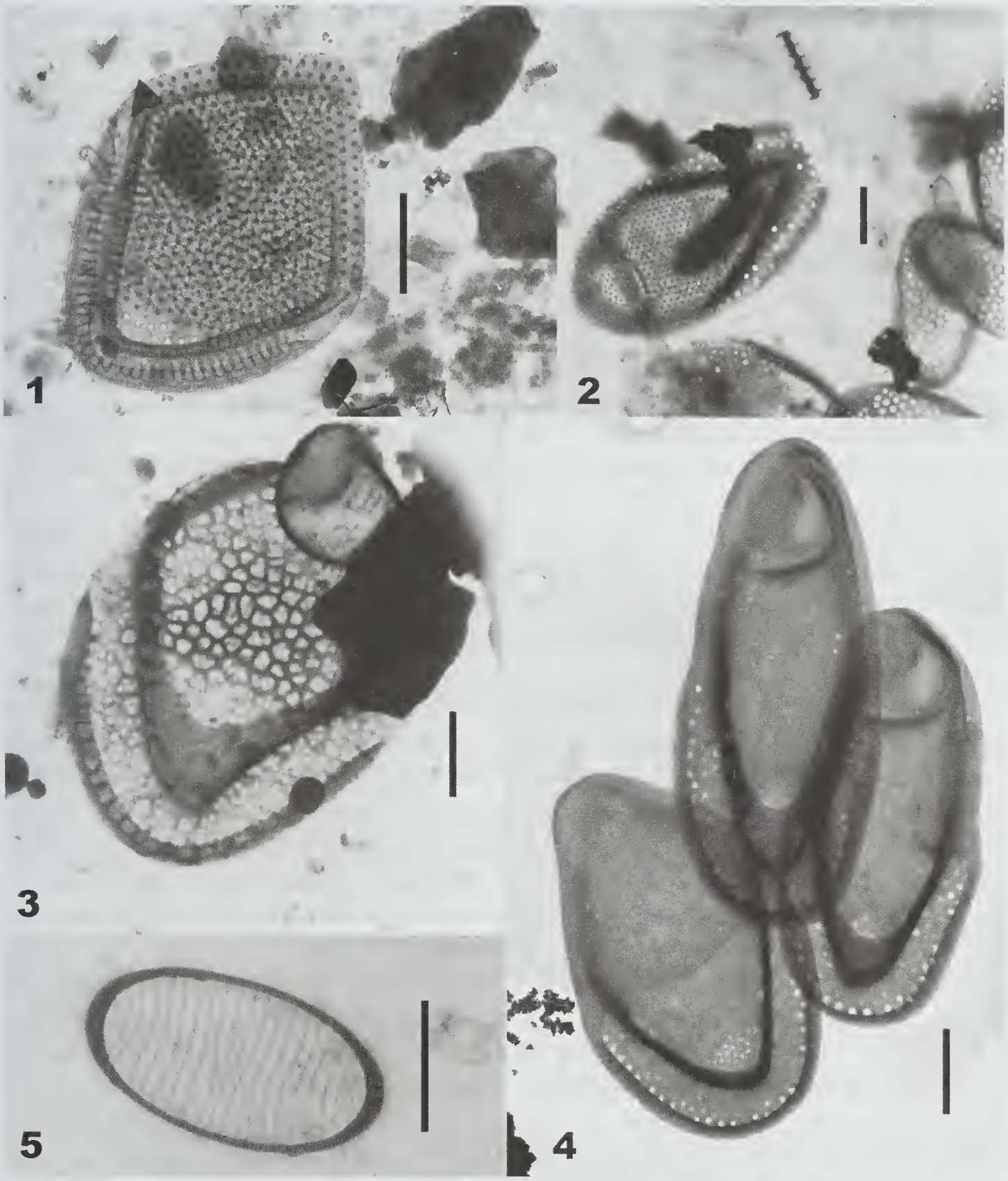
A cosmopolitan species, TEM reports include ten North American locations (Kristiansen 2002). The body scales, rhombic in outline, are marked with evenly spaced papillae and small scattered pores near the base of the scale. I observed it only once from a Mecosta Co. location, School Section Lake.

Mallomonas multisetigera Dürrschmidt Fig. 2.

This taxon has been reported from a number of worldwide locations (Kristiansen 2002). Its epithet refers to the numerous bristles (not illustrated) all over the body. I observed it from collections made in Smith's Bog, Cheboygan Co. and Lake Geneserath, Beaver Island, Charlevoix Co.

Mallomonas portae-ferreae var. *reticulata* Gretz, Sommerfeld & Wujek Fig. 3.

This variety was described from collections made in Arizona (Gretz et al. 1985). Subsequent records are mainly from South America (see Kristiansen 2002; Wujek & Bicudo 2004). The most recent records from the U.S. are from the southern states of Florida and Louisiana (Wujek & Wright 2005; Wujek & Wee 2006). The scales of this variety are separated from variety *portae-ferreae* which possess up to ten transverse, regular spaced, slightly curved ribs which are occasionally interconnected by cross ribs to form patches of reticulation. My ob-



FIGURES 1-4. Silica-scales from the chrysophyte alga *Mallomonas*. 1. *M. mangofera* var. *mangofera,* body scale. 2. *M. multisetigera,* body scale. 3. *M. portae-ferreae* var. *reticulata,* dome-bearing body scale. 4. *M. variabilis,* three body scales. FIGURE 5. *Pseudodendromonas vlkii,* scale. Scale bars = 1 μm.

servation of it from Bass Lake, Montcalm Co., represents its most northern distribution in North America.

Mallomonas variabilis Cronberg Fig. 4.

Described originally from Finland (Cronberg 1995), it has a north temperate distribution, being previously reported from Canada (Kling & Kristiansen 2001) and Greenland (Wilken et al. 1995). It can be distinguished from two similar

species, *Mallomonas tonsurata* and *M. alpina* only by using EM. Both of these latter species have previously been reported as occurring in Michigan (Wujek & Hamilton 1972, 1973). The most characteristic feature of the scales is the variable presence of short, irregularly distributed ridges on the shield. A well developed V-rib, sometimes hooded (present on two of the three illustrated scales) and large pores along the posterior margin also help distinguish its scales. *Mallomonas variabilis* was observed from the Lake Lansing, Ingham Co. and Lake Skegemog, Antrim Co. samples.

Pseudodendromonas vlkii Bourrelly Fig. 5

Pseudodendromonas is a colorless organism. It is a colonial relative of the zooflagellate *Cyathobodo*. Hibberd (1985) placed the genus within the order Pseudodendromonadida. Cavalier-Smith (1993) placed the Pseudodendromonadida in the class Cyathobodonea within the phylum Opalozoa. Karpov (2000) recently recognized still another order, the Bicosoecida, into which he placed *Pseudodendromonas* as a member of his newly described family Pseudodendromonadidae. I observed scales of *P. vlkii* from Little Tom Lake and Coldwater Lake (Table 1). Previous U.S. locations are from Alabama (Wujek & Menapace 1998), Mississippi (Wujek 1999), the Carolinas (Wujek et al. 2004a, b), and New York (Wujek et al. 2006).

In conclusion, as has been demonstrated for other regions in the U.S., Michigan supports a diverse flora of silica-scaled chrysophytes. Further collections and observations from other localities in the state, particularly the Upper Peninsula which to date has been under investigated, as well as sampling over an annual cycle should yield additional taxa. The silica-scaled chrysophytes (Chrysophyceae and Synurophyceae) found in Michigan based on EM studies now include 87 taxa; of these, four are newly reported including a new U.S. record. This total is slightly more than the 71 taxa reported from Louisiana (Wee et al. 1993; Wujek & Wee 2006), 73 from Florida (Siver & Wujek 1999; Wujek & Wright 2005 and literature therein), 64 from New York (Wujek et al. 2006), but less than the 105 from the Carolinas (Wujek 2000; Wujek & Elsner 2000; Wujek & Carter 2002; Wujek & Wright 2005; Wujek et al. 2004a, b), states in which, in several cases, the silica-scaled chrysophyte flora and algae in general have been more intensely studied. However, it is greater than the 45 taxa reported from Alabama (Wujek & Menapace 1998) and 36 taxa from Mississippi (Wujek 1999).

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SISTER M. VINCENT DE PAUL AND THE TYPIFICATION OF THE NAME *POLYGONATUM COMMUTATUM* FORMA *RAMOSUM* MCGIVNEY (CONVALLARIACEAE)

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ABSTRACT

A brief biographical sketch of Sister Vincent de Paul McGivney (1886–1958), a little known Michigan botanist, is elaborated as a prelude to typifying the only plant she named, *Polygonatum commutatum* forma *ramosum*, described from Indiana and Michigan.

KEYWORDS: *Polygonatum*, typification, biography, Sister Vincent de Paul McGivney

Sister Vincent de Paul (Marguerite Helena) McGivney I.H.M. (Jan. 21, 1886–Feb. 19, 1958)—known as Margaret to the I.H.M. (Immaculate Heart of Mary) Community—is one of the least well known of botanists who have spent a large portion of their careers in Michigan. A native of Howell, Michigan, after completing an A.B. degree at the University of Michigan in 1910, she entered the Novitiate I.H.M. Sisters in Monroe, Michigan. She went on to teach at Catholic high schools in Monroe, Detroit, and Flint until 1927. During the summers of 1924 through 1927, she attended the University of Notre Dame where she completed a Master's degree under J. A. Nieuwland (Notes on our local plants. Notre Dame, Indiana, 1927. 15 pp.). Her chief contributions to Michigan botany were her teaching at Marygrove College, where she was on the faculty from the founding of the school in 1927 until 1957 and founded the Marygrove College herbarium, and her collecting, especially in SE Michigan, during the same period. During her tenure at Marygrove, she worked full-time at the Catholic University of America from September 1934 to January 1937, completing a Ph.D. thesis under Hugh O'Neill. It was published in 1938 as The Catholic University of America Biological Series No. 26: A Revision of the subgenus Eucyperus Found in the United States.

Thanks to the kindness of Marygrove College, the Marygrove College Herbarium now has been incorporated into the University of Michigan Herbarium. Besides many hundreds of her and her colleagues' collections from Michigan, there are also large numbers of collections from the vicinity of Notre Dame, Indiana, made during her Master's work, and large numbers from the vicinity of

Washington, D.C., made during her Ph.D. work. While at Marygrove, she exchanged with several herbaria, so the herbarium included exchange material from the University of Kansas (KANU), the Catholic University of America (herbarium now dispersed: see Taxon 38: 196–203. 1989), and Butler University (BUT), and her collections are also in those institutions.

While her major botanical contribution was the publication on *Cyperus* resulting from her Ph.D. thesis, noted above, the only plant she actually named (and the reason her name is in botanical indices such as IPNI) is a remarkable branched form of *Polygonatum biflorum* (Walter) Ell. (Amer. Midl. Naturalist 9(12): 662–664, as *P. commutatum* forma *ramosum)*. This name, however, though of a minor form, presents substantial typification problems. Two collections from the University of Notre Dame Herbarium (ND) were cited: the type, "*Planta 22003, Nostrae Dominae, Ind., in sylva sub Quercus die 14 Julii, 1925*" and "*22002 proxima Lacu Christiana, Mich. australi menses Aug. 10, 1924.*" No collector was given for either specimen and the numbers in the publication are suspiciously regular, with the two collections from different years in adjacent states in reverse chronological order, and were presumably invented for this publication to identify specific collections in ND.

ND has six sheets referable to this plant; unfortunately, none of them bear either number, and none have dates that match those cited in the publication. Three sheets can be firmly eliminated from consideration as types because they were collected in years after or before those cited; one from Indiana in 1924, one from Indiana in 1929, and one from Indiana in 1930. A fourth sheet is from the cited locality in Michigan, Christiana Lake (Cass County), but the date is Aug. 7, 1924, instead of Aug. 10. No collector is given on this sheet. The small discrepancy of the date notwithstanding, this specimen may well be a paratype. In any event, it is the only Michigan collection available. The last two of the six ND sheets were collected at Notre Dame, Indiana in 1925. They are apparent duplicates and both bear the date July 10 and were collected by J.A. Nieuwland. One is named *Polygonatum commutatum* forma *ramosum* and has Nieuwland's collection number of 15151 and a note by him "about 6 plants found, 4 left only two collected JAN[ieuwland]." The other collection, presumably the second individual alluded to, does not have a collection number, is named only *Polygonatum commutatum*, and has "teratological specimen" in parentheses. At the bottom of the label in pencil in another hand is the small blurry notation "S.M.V. de P." for Sister M. Vincent de Paul McGivney. The 1924 Indiana sheet was from Notre Dame, dated July 26, and presumably means Nieuwland first found the plant the year before the collection of the type. Interestingly, this sheet suggests that there was more than one patch, since there was a note on the label "300 yards away from 15151."

This leaves the typification in an unsatisfactory state because of the date discrepancy, the fact that neither specimen at ND has any habitat notation (cited as "*in sylva sub Quercus*" in the publication), and the lack of connection to Sister Vincent de Paul (except for the mysterious small pencil notation on one of the Nieuwland collections).

As noted above, the University of Michigan recently acquired the Herbarium of Marygrove College, which was for many years the home institution of Sister

Vincent de Paul. Because ND had no Sister Vincent de Paul collections, we believe she brought with her the collections she made in the Notre Dame area. In this collection we located two sheets collected by her and fully labeled *Polygonatum commutatum* forma *ramosum* McGivney from near Notre Dame with the date given as "July 1925" and the habitat "woods."

Despite the original publication noting the type as at ND, we consider the possibility that the good sister kept the specimens longer than intended, and her specimens from the Marygrove Herbarium may represent the type collection. These specimens, though lacking a specific day, at least do not contradict the type citation, have at least the partial habitat "woods," and are firmly connected to Sister Vincent de Paul. These two sheets clearly represent a gathering different than the Nieuwland collection; the condition and pressing of the Sister Vincent de Paul sheets is quite dissimilar. Since Nieuwland said, on the label of one of his two July 10, 1925 collections, "only two collected," it appears that Sister Vincent De Paul went out a few days later to the colony and gathered two more in preparation for describing this entity—but evidently failed to follow through with depositing the type specimen at ND with a more complete label appropriate for a type. This action would also account for the published numbers not being placed on any sheets.

Since the Sister Vincent de Paul collections were clearly a different gathering, we checked briefly to see if they might be a better match for the description and illustration of *Polygonatum commutatum* forma *ramosum* than the two Nieuwland sheets in ND. Unfortunately, the description was sparse and the illustration somewhat stylized, so our conclusions are only suggestive. Her description calls for "about 15 leaves 8–10 cm long and 4–5 cm wide" and the illustration shows 15 main stem leaves. The two Nieuwland sheets have 16 and 18+ leaves, while the two Sister Vincent De Paul sheets each have 15 leaves. The lengths of the leaves of the Sister Vincent De Paul sheets are also closer to the description—the largest being 9–10 cm long while the two Nieuwland sheets have the largest leaves 11 cm long. The illustration also shows a lower branch with 3 fruits on a common peduncle, which is present on one of the Sister Vincent De Paul sheets but not on either of the Nieuwland sheets.

There can be no doubt that these highly branched specimens represent the same teratology, and probably even the same clone, so in some senses the precise typification is moot. But in the interests of precision, we suggest that the Sister Vincent de Paul sheet from the Marygrove herbarium that appears to most closely match the description is likely the holotype, which we have now deposited in ND, perhaps fulfilling the Sister's wish posthumously, and the other sheet is an isotype; the full citation is:

Polygonatum commutatum **forma** ***ramosum*** **McGivney**, Amer. Midl. Naturalist 9(12): 664. 1925. Type: INDIANA [St. Joseph Co.], Woods near Notre Dame, Sister Vincent de Paul [McGivney], [14] July, 1925. Holotype: ND, Isotype MICH. *Polygonatum canaliculatum* forma *ramosum* (McGivney) Clute, Amer. Bot. (Binghamton) 49: 73. 1943; *Polygonatum biflorum* forma *ramosum* (McGivney) Fernald, Rhodora 46: 12. 1944.

There are perhaps other possible scenarios to account for the discrepancies. If the Nieuwland sheets are assumed to be types, we would then have to assume

Figure 1. Original illustration of *Polygonatum commutatum* forma *ramosum* McGivney reproduced with permission from Amer. Midl. Naturalist 9(12): 662. 1925.

that the date cited in the publication is wrong, that she failed to note Nieuwland as collector, and that she added information about the habitat from her observations, but did not mention her own collections. But we hope the apparent slightly better match of the Sister Vincent de Paul collections with the publication adds some weight to our scenario being likely.

Because this plant is such a curiosity, we here also reproduce the original illustration published with the description as Fig. 1. Fortunately, the four stems collected in 1925 did not extirpate this remarkable plant, as it evidently became well known to botanists in the late 1920's, with collections of the same plant having been made by P.E. Hebert in 1929 (ND), M.W. Lyon also in 1929 (MICH), and Nieuwland again in 1930 (ND). The Hebert collection contains the more precise locality: Angela ["Angella"] Ravine. Furthermore, at some point, living material was transferred to a garden at Marygrove College, whence collections were made as recently as 1948 as *Polygonatum biflorum* (Walt.) Ell. forma *ramosum* McGivney (introduced), Marygrove College Campus, Sept. 2, 1948, Sister Vincent de Paul s.n., (KANU).

One final note is that in her paper, she describes the location as "one mile southeast of the University." However, Angela Ravine is actually ca. 1 mile WSW of the University and those few collections that do give more precise localities than just "Notre Dame" or "near Notre Dame" also give the locality as "west" or "southwest" of the University. We believe that all the collections are from the same general locality, Angela Ravine. Even in 1925, southeast of the University would have been urban/residential with no woods.

This work would not have been possible without Dr. Donald Rizzo from the Biology Department at Marygrove College realizing the scientific importance of the collection that Sister Vincent de Paul had amassed and arranging for its donation to the University of Michigan. We thank Bonnie Isaac (CM) and Ted Cochrane (WIS) for searching for additional McGivney collections; Craig Freeman (KANU) for hospitality during Rabeler's visit and later providing label data; Diane Puhl and Dr. Donald Rizzo from Marygrove College and Donna Wesley, archivist, I.H.M. Motherhouse, Monroe, Michigan, for providing biographical information for Sister Vincent de Paul including her birth and death dates; and Ed Voss for his comments on a draft of this article.

HURON MOUNTAIN CLUB BRYOPHYTE AND LICHEN COLLECTION DEPOSITED AT NORTHERN MICHIGAN UNIVERSITY

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ABSTRACT

This paper reports the transfer of the Manierre collection of nonvascular plants from the Huron Mountain Club to the Herbarium of Northern Michigan University in Marquette where, upon application, it is now available for scientific study. The collection contains specimens of 701 species or near species of mosses, liverworts, lichens and hornworts in approximately 291 genera including a large number of rarities—all collected within the 20,000 acres of the protected lands of the Huron Mountain Club. The timing of this announcement is peculiarly appropriate as the threat of sulfide mining at the headwaters of the Salmon Trout River becomes increasingly imminent.

My extensive collection of bryophytes and lichens collected over the course of 20 years at the Huron Mountain Club (Marquette County, Michigan) has been placed in the Herbarium of Northern Michigan University (NMU). Value of this collection results, in part, from limitation to a specific area of approximately 20,000 acres well known for the biodiversity of their old growth forests, the purity of their lakes and streams, and their unique geology (Wilson 1990). The large number of taxa represented here and the high degree of rarity among them suggest the environmental importance of this protected private holding.

The collection contains 290 species or near species of mosses, 83 of liverworts, 327 of lichens and a lone hornwort *Phaeoceros laevis* (L.). Thus, this holding represents slightly more mosses than the Keweenaw Peninsula (Glime & Slavick 1985), more lichens than the Pictured Rocks National Lakeshore (Wetmore 1988), 67% of the lichens reported from Isle Royale National Park (Wetmore 1985), and no less than 80 species not yet reported from that fertile location which is approximately seven times larger than the Club.

The Huron Mountain Club is presently the only known existing location in the Western Hemisphere for the moss *Gyroweisia reflexa* (Brid.) Schimp. (Manierre 1998) and the finding there in 1998 of *Caloplaca invadens* Lynge (Manierre 1999b) marks the first time this lichen has been found within the lower 48 states. Eight additional taxa were reported here as "first finds for the state of Michigan": the mosses *Bryum alpinum* Huds. *ex* With. (Manierre 2001b), *Eurynchium praelongum* (Hedw.) Schimp. *in* B.S.G. (Manierre 1999b), *Grimmia anodon* Bruch & Schimp. (Manierre 1999a), *Grimmia donniana* Sm. (Manierre 2001b), *Leskea polycarpa* Hedw. (Manierre 1999a), *Physcomitrium immersum* Sull. (Manierre 1999a), *Pseudoleskeela sibirica* (Arnell) P. Wils. &

Norris (Manierre 1999b) and the lichen *Solorina spongiosa* (Ach.) Anzi. (Manierre 1999b) (see cover).

As further indication of the botanical richness of this venue I cite the following ten additional rarities: *Bryum muehlenbeckii* Bruch & Schimp. (Manierre 1999a), *Ephemerum spinulosum* Bruch & Schimp. (Manierre 1999a), *Fabronia ciliaris* (Brid.) Brid. *var. ciliaris* (Manierre 1999a), *Gyroweisia tenuis* (Hedw.) Schimp. (Manierre 1999a), *Philonotis capillaris* Lindb. *in* Hartm. (Manierre 1999a), *Seligeria campylopoda* Kindb. *in* Mac. & Kindb. (Manierre 1999a), *Sphagnum quinquefarium* (Lindb. *ex* Braithw.) Warnst. (Manierre 1999b), *Sphagnum riparium* Aöngst. (Manierre 1999b) for the mosses and *Phaeoceros laevis* (L.) Prosk. subsp. *laevis* (Manierre 1999a) and *Lophozia obtusa* (Lindb.) Evans (Manierre 1999a) for the hornworts and liverworts respectively. Specimens of the above rarities for Upper Michigan are in the Herbarium of the University of Michigan except for *Caloplaca invadens*, *Lophozia obtusa* and *Fabronia ciliaris* my collections of which being too small for division.

Identifications were scrupulously attended to. By far the most were made by Dr. Howard Crum of the University of Michigan whose many contributions to the project made it possible and whose death in 2002 brought it to an end. I would collect at Huron Mountain for six months each summer and identify what I could. During the remaining six months of the year I would meet weekly in Ann Arbor with Dr. Crum in his University of Michigan Herbarium office where we would ponder together at meetings of two to three hours each over taxa that had proved too difficult for me. This routine continued for better than fifteen years during which Dr. Crum gave to the project an estimated seven hundred hours of his personal time. He examined just about every item in the collection—probably 95% of the bryophytes and a large portion of the lichens—not to mention the lone hornwort which particularly pleased him.

Dr. Crum was somewhat less sure of the lichens and, while identifying many of these himself, he would occasionally send difficult ones to other specialists in order to obtain the greatest accuracy possible. Among these are the following, to each of whom most sincere thanks are due and herewith tendered: Bruce Allen, Irwin M. Brodo, William R. Buck, Alan M. Fryday, Richard C. Harris, Norton G. Miller, John W. Thomson, Dale H. Vitt, Clifford M. Wetmore, and special thanks for technical assistance and advice to Dr. Dana L. Richter of Michigan Technological University.

A complete list of bryophyte and lichen species found at the Huron Mountain Club is provided in the Appendix and can also be viewed by visiting the Huron Mountain Wildlife Foundation website, http://www.hmwf.org. Specimens of all taxa on the list are held in the Herbarium NMU with the exception of 18 lichens that were collected in 1949 and 1976 by Henry A. Imshaug and James Malachowske. Of these, 16 are deposited at MSC while two are at MICH where are also found duplicates of some of the rarer items mentioned in this paper. Further information regarding this collection is available upon request to Dr. Alan Rebertus, Curator of the Herbarium, Biology Department, Northern Michigan University, Marquette, MI 49855, email arebertu@nmu.edu, TEL. 906-227-2351.

Coincidentally, this announcement, submitted for publication to *The Michigan Botanist*, follows close upon the appearance on the "Web" of Professor Kerry D.

Woods' "All-Taxa Biodiversity Inventory of the Huron Mountain Club," which includes 4321 "documented species". This inventory culminates approximately one hundred years of increasingly serious scientific activity at that location and, latterly, through the auspices of the Huron Mountain Wildlife Foundation. Dr. Woods stresses that the "Inventory" is not a finished product. Rather, it is ongoing, subject to continual revision; addition, correction, and where necessary reduction as species die out or simply disappear. With this in mind, it is reasonable to hope that government supported sulfide mining in The Yellowdog Plains, adjacent to the Huron Mountain Club, does not spell "culminate" with a capital "C".

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APPENDIX

MOSSES, LIVERWORTS, & HORNWORTS
Phylum BRYOPHYTA
Class Sphagnopsida
Order Sphagnales
Family Sphagnaceae
Sphagnum angustifolium
Sphagnum capillifolium
Sphagnum centrale
Sphagnum compactum
Sphagnum contortum
Sphagnum cuspidatum
Sphagnum fallax
Sphagnum fimbriatum
Sphagnum fuscum
Sphagnum girgensohnii
Sphagnum lescurii
Sphagnum magellanicum
Sphagnum magus
Sphagnum papillosum
Sphagnum pulchrum
Sphagnum pulustre
Sphagnum quinquefarium
Sphagnum recurvum
Sphagnum riparium
Sphagnum rubellum
Sphagnum russowii
Sphagnum squarrosum
Sphagnum subsecundum
Sphagnum tenellum
Sphagnum tenerum
Sphagnum teres
Sphagnum warnstorfii

Sphagnum wulfianum
Class Andreaeopsida
Order Andreaeales
Family Andreaeaceae
Andreaea rothii
Andreaea rupestris
Andreaea rupestris var. *papillosa*
Class Bryopsida
Order Tetraphidales
Family Tetraphidaceae
Tetraphis pellucida
Order Buxbaumiales
Family Buxbaumiaceae
Buxbaumia aphylla
Order Polytrichales
Family Polytrichaceae
Atrichum angustatum
Atrichum undulatum
Polytrichastrum alpinum var. *alpinum*
Polytrichum commune var. *commune*
Polytrichum commune var. *perigoniale*
Polytrichum formosum
Polytrichum juniperinum
Polytrichum piliferum
Polytrichum strictum
Order Buxbaumiales
Family Diphysciaceae
Diphyscium foliosum
Order Encalyptales
Family Encalyptaceae
Encalypta ciliata
Encalypta procera
Order Funariales
Family Funariaceae
Funaria hygrometrica
Physcomitrium immersum
Family Ephemeraceae
Ephemerum spinulosum
Order Grimmiales
Family Grimmiaceae
Dryptodon patens
Grimmia affinis
Grimmia anodon
Grimmia anomala
Grimmia donniana
Grimmia hermannii
Grimmia olneyi
Grimmia pilifera
Grimmia tenerrima
Grimmia teretinervis
Grimmia trichophylla
Grimmia unicolor
Racomitrium aciculare
Racomitrium canescens var. *canescens*
Racomitrium ericoides
Racomitrium fasciculare
Racomitrium heterostichum
Racomitrium microcarpon
Racomitrium sudeticum
Schistidium apocarpum
Schistidium rivulare var. *rivula*re
Order Seligeriales
Family Seligeriaceae
Blindia acuta
Seligeria campylopoda
Seligeria pusilla
Seligeria recurvata
Order Dicranales
Family Fissidentaceae
Fissidens adianthoides
Fissidens bryoides
Fissidens bryoides "*minutulus* expression"
Fissidens dubius
Fissidens osmundioides
Fissidens taxifolius
Family Dicranaceae
Cynodontium schisti
Cynodontium strumiferum
Cynodontium tenellum
Dichodontium pellucidum
Dicranella grevilleana
Dicranella heteromalla
Dicranella varia
Dicranoweisia crispula
Dicranum condensatum
Dicranum flagellare
Dicranum fulvum
Dicranum fuscescens var. *fuscescens*
Dicranum montanum
Dicranum muehlenbeckii
Dicranum ontariense
Dicranum polysetum
Dicranum scoparium
Dicranum spurium
Dicranum undulatum
Dicranum viride
Oncophorus virens
Oncophorus wahlenbergii
Paraleucobryum longifolium
Family Bruchiaceae
Trematodon ambiguus
Family Leucobryaceae
Leucobryum glaucum
Family Ditrichaceae
Ceratodon purpureus var. *purpureus*
Distichium capillaceum var. *capillaceum*
Ditrichum pusillum
Saelania glaucescens
Family Rhabdoweisiaceae
Rhabdoweisia crispata
Order Pottiales
Family Pottiaceae
Bryoerythrophyllum recurvum
Didymodon fallax var. *fallax*
Didymodon rigidulus var. *rigidulus*
Gymnostomum aeruginosum
Gyroweisia reflexa
Gyroweisia tenuis

Oxystegus tenuirostris
Plaubelia springellii
Tortella tortuosa
Tortula mucronifolia
Tortula ruralis

Order Splachnales

Family Splachnaceae

Splachnum ampullaceum
Tetraplodon angustatus

Order Orthotrichales

Family Orthotrichaceae

Orthotrichum affine
Orthotrichum anomalum
Orthotrichum obtusifolium
Orthotrichum sordidum
Orthotrichum speciosum var. *elegans*
Ulota crispa
Ulota hutchinsiae var. *rufescens*
Ulota hutchinsiae var. *hutchinsiae*

Order Hedwigiales

Family Hedwigiaceae

Hedwigia ciliata

Order Bryales

Family Aulacomniaceae

Aulacomnium androgynum
Aulacomnium palustre var. *imbricatum*
Aulacomnium palustre

Family Bartramiaceae

Bartramia pomiformis
Philonotis capillaris
Philonotis fontana var. *caespitosa*
Philonotis fontana var. *fontana*
Philonotis fontana var. *pumila*

Family Bryaceae

Bryum algovicum var. *algovicum*
Bryum alpinum
Bryum argenteum
Bryum argenteum var. *lanateum*
Bryum caespiticium
Bryum capillare var. *capillare*
Bryum flaccidum
Bryum lisae var. *cuspidatum*
Bryum muehlenbeckii
Bryum pallens
Bryum pallescens
Bryum pseudotriquetrum
Bryum ruderale
Bryum violaceum
Pohlia bulbifera
Pohlia cruda
Pohlia nutans
Pohlia proligera
Pohlia wahlenbergii

Family Mniaceae

Cyrtomnium hymenophylloides
Mnium ambiguum
Mnium marginatum
Mnium spinulosum
Mnium thomsonii
Plagiomnium ciliare
Plagiomnium cuspidatum
Plagiomnium ellipticum
Plagiomnium medium var. *medium*
Plagiomnium rostratum
Pseudobryum cinclidioides
Rhizomnium appalachianum
Rhizomnium magnifolium
Rhizomnium pseudopunctatum
Rhizomnium punctatum

Order Hypnales

Family Amblystegiaceae

Amblystegium serpens var. *juratzkanum*
Amblystegium serpens var. *serpens*
Amblystegium varium
Calliergonella cuspidata
Hygroamblystegium luridum
Hygroamblystegium fluviatile
Hygroamblystegium tenax var. *tenax*
Leptodictyum humile
Leptodictyum riparium

Family Cratoneuraceae

Cratoneuron filicinum

Family Helodiaceae

Helodium blandowii var. *blandowii*

Family Hylocomiaceae

Hylocomiastrum pyrenaicum
Hylocomium splendens
Pleurozium schreberi
Rhytidiadelphus squarrosus
Rhytidiadelphus triquetrus

Family Leskeaceae

Leskea gracilescens
Leskea polycarpa
Leskeella nervosa
Lindbergia brachyptera
Pseudoleskeella sibirica

Family Pterigynandraceae

Heterocladium dimorphum
Heterocladium macounii
Myurella julacea
Myurella sibirica
Myurella anomalous form
Pterigynandrum filiforme

Family Thuidiaceae

Abietinella abietina
Thuidium delicatulum
Thuidium philibertii
Thuidium recognitum

Family Campyliaceae

Calliergon cordifolium
Calliergon giganteum
Calliergon stramineum
Campylium chrysophyllum
Campylium hispidulum
Campylium polygamum
Campylium radicale
Campylium stellatum var. *stellatum*
Campylium stellatum var. *protensum*

Drepanocladus aduncus var. *kneiffii*
Drepanocladus aduncus var. *aduncus*
Hygrohypnum molle
Hygrohypnum ochraceum
Limprichtia cossonii
Sanionia uncinata var. *uncinata*
Tomentypnum falcifolium
Warnstorfia fluitans var. *fluitans*

Family Brachytheciaceae
Brachythecium acuminatum
Brachythecium oedipodium
Brachythecium oxycladon
Brachythecium plumosum
Brachythecium populeum
Brachythecium reflexum var. *reflexum*
Brachythecium rivulare
Brachythecium rutabulum
Brachythecium salebrosum var. *salebrosum*
Brachythecium turgidum
Brachythecium velutinum var. *velutinum*
Bryhnia graminicolor
Brylinia novae-angliae
Eurhynchium hians
Eurhynchium praelongum
Eurhynchium pulchellum var. *pulchellum*
Platyhypnidium riparioides
Steerecleus serrulatus

Family Fabroniaceae
Fabronia ciliaris var. *ciliaris*

Family Plagiotheciaceae
Plagiothecium cavifolium
Plagiothecium denticulatum
Plagiothecium laetum

Family Fontinalaceae
Dichelyma capillaceum
Dichelyma pallescens
Fontinalis antipyretica var. *antipyretica*
Fontinalis antipyretica var. *gigantea*
Fontinalis dalecarlica
Fontinalis flaccida
Fontinalis hypnoides var. *duriaei*
Fontinalis missourica
Fontinalis neomexicana
Fontinalis novae-angliae var. *novae-angliae*
Fontinalis sullivantii

Family Climaciaceae
Climacium americanum
Climacium dendroides

Family Hypnaceae
Callicladium haldanianum
Ctenidium molluscum
Herzogiella turfacea
Homomallium adnatum
Hypnum cupressiforme var. *resupinatum*
Hypnum curvifolium
Hypnum fertile
Hypnum lindbergii
Hypnum pallescens var. *protuberans*
Hypnum pallescens var. *pallescens*
Hypnum pratense
Isopterygiopsis pulchella
Platydictya confervoides
Platydictya subtilis
Platygyrium repens
Pseudotaxiphyllum distichaceum
Pseudotaxiphyllum elegans
Ptilium crista-castrensis
Pylaisiella polyantha
Pylaisiella selwynii
Taxiphyllum deplanatum

Family Sematophyllaceae
Brotherella recurvans

Family Leucodontaceae
Leucodon brachypus var. *andrewsianus*

Family Neckeraceae
Homalia trichomanoides
Neckera pennata

Family Anomodontaceae
Anomodon tristis
Anomodon attenuatus
Anomodon minor
Anomodon rostratus
Anomodon rugelii

Phylum MARCHANTIOPHYTA

Class Marchantiopsida

Order Marchantiales

Family Conocephalaceae
Conocephalum conicum

Family Marchantiaceae
Marchantia polymorpha
Preissia quadrata

Class Jungermanniopsida

Order Metzgeriales

Family Blasiaceae
Blasia pusilla

Family Pelliaceae
Pellia epiphylla
Pellia megaspora
Pellia neesiana

Family Pallaviciniaceae
Moerckia hibernica
Pallavicinia lyellii

Family Aneuraceae
Riccardia multifida var. *multifida*

Family Metzgeriaceae
Metzgeria conjugata
Metzgeria furcata var. *furcata*
Metzgeria furcata var. *ulvula*

Order Jungermanniales

Family Ptilidiaceae
Ptilidium ciliare
Ptilidium pulcherrimum

Family Trichocoleaceae
Trichocolea tomentella

Family Pseudolepicoleaceae
Blepharostoma trichophyllum subsp. *trichophyllum*

Family Geocalycaceae
Chiloscyphus pallescens var. *pallescens*
Chiloscyphus pallescens var. *fragilis*
Chiloscyphus polyanthos var. *polyanthos*
Chiloscyphus polyanthos var. *rivularis*
Geocalyx graveolens
Lophocolea heterophylla
Lophocolea minor
Family Plagiochilaceae
Plagiochila porelloides
Family Calypogeiaceae
Calypogeia trichomanis
Family Lepidoziaceae
Bazzania trilobata var. *trilobata*
Lepidozia reptans
Family Cephaloziaceae
Cephalozia bicuspidata ssp. *Bicuspidata*
Cephalozia connivens var. *connivens*
Cephalozia loitlesbergeri
Cephalozia macounii
Cephalozia pleniceps var. *pleniceps*
Odontoschisma denudatum var. *denudatum*
Family Cephaloziellaceae
Cephaloziella divaricata var. *divaricata*
Cephaloziella hampeana
Cephaloziella rubella
Family Jungermanniaceae
Anastrophyllum helleranum
Anastrophyllum michauxii
Anastrophyllum minutum var. *minutum*
Barbilophozia attenuata
Barbilophozia barbata
Barbilophozia floerkei var. *floerkei*
Barbilophozia hatcheri
Barbilophozia kunzeana
Barbilophozia lycopodioides
Jamesoniella autumnalis var. *autumnalis*
Jungermannia crenuliformis
Jungermannia exsertifolia subsp. *cordifolia* var. *cordifolia*
Jungermannia gracillima
Jungermannia leiantha
Jungermannia pumila
Lophozia incisa var. *incisa*
Lophozia obtusa
Lophozia sudetica
Lophozia ventricosa var. *ventricosa*
Tritomaria exsectiformis subsp. *exsectiformis*
Tritomaria quinquedentata var. *quinquedentata*
Family Gymnomitriaceae
Marsupella emarginata subsp. *emarginata*
Marsupella emarginata subsp. *emarginata* var. *emarginata*
Family Scapaniaceae
Scapania curta var. *curta*
Scapania cuspiduligera var. *cuspiduligera*
Scapania irrigua subsp. *irrigua*
Scapania mucronata subsp. *mucronata*
Scapania nemorosa
Scapania subalpina
Scapania umbrosa
Scapania undulata var. *undulata*
Family Porellaceae
Porella pinnata
Porella platyphylla
Porella platyphylloidea
Family Jubulaceae
Frullania bolanderi
Frullania brittoniae
Frullania eboracensis
Frullania inflata
Frullania oakesiana
Frullania selwyniana
Frullania tamarisci subsp. *asagrayana*
Family Lejeuneaceae
Cololejeunea biddlecomiae
Lejeunea cavifolia
Lejeunea lamacerina subsp. *genuminata*
Family Radulaceae
Radula complanata
Radula obconica

Phylum ANTHOCEROTOPHYTA
Class Anthocerotopsida
Order Anthocerotales
Family Anthocerotaceae
Phaeoceros laevis subsp. *laevis*

LICHENS
Phylum ASCOMYCOTA
Class Euascomycetes
Order Leotiales
Family Baeomycetaceae
Baeomyces rufus
Icmadophila ericetorum
Order Ostropales
Family Graphidaceae
Graphis scripta
Family Stictidaceae
Conotrema urceolatum
Family Thelotremataceae
Diploschistes scruposus
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Cladonia acuminata
Cladonia acuminata var. *acuminata*
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Cladonia cristatella
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Family Hymeneliaceae
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Aspicilia cinerea
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Lecanora argopholis
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Nephroma parile
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Allocetraria oakesiana
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Flavopunctelia soredica
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Umbilicaria muehlenbergii
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Umbilicaria vellea
Umbilicaria virginis

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Family Monoblastiaceae
Acrocordia megalospora

Order Verrucariales

Family Verrucariaceae
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Dermatocarpon miniatum
Dermatocarpon moulinsii
Staurothele areolata
Staurothele fissa
Verrucaria sp.

Non-fertile, uncertain position
Lepraria caeioalba
Lepraria incana
Lepraria lobificans
Lepraria neglecta

NOTEWORTHY COLLECTION

OHIO

Hydrocharis morsus-ranae L. (Hydrocharitaceae). Common Frog-bit.

Previous knowledge. A native of Eurasia, *H. morsus-ranae* was introduced into North America in Ontario, Canada, as early as 1932 for horticultural purposes (Catling and Dore 1982). First United States locality was discovered in New York in 1974 (Roberts *et al.* 1981). Its current range is throughout much of central and southwestern parts of southern Ontario into northern New York, Vermont, and eastern Michigan as well as Washington state (Catling *et al.* 2003). In the Great Lakes, this species occurs along Lake Erie and Lake Ontario as well as St. Lawrence and Ottawa Rivers.

Diagnostic characters. Hydrocharis morsus-ranae is a herbaceous, stoloniferous perennial aquatic with white flowers and cordate-orbicular leaves. It is similar to the native *Limnobium spongia* but has 2 stipules compared to 1, which are lateral and free from the petiole as well as the petals being more than 1.5 times as long as the sepals compared to less than 1.5 times. Blooming period is from June to September. *Hydrocharis morsus-ranae* is dioecious and some colonies can be only one sex (Catling and Dore 1982). It reproduces both sexually and asexually. Stolons and overwintering turions are its primary means of propagation.

Significance of the report. This is the first documented report of this invasive species in Ohio (Cooperrider *et al.* 2001; Haynes 2000). The Ohio locality is also the first for the southern coastline of Lake Erie. It was collected in the summer of 2004, on wet muck at the edge of a large, diked marsh in Cedar Point National Wildlife Refuge, a 2245-acre refuge in Lucas County (41° 41′ 42″ N 83°19′ 57″ W). The marsh is a mosaic of mixed emergent and submergent marsh communities with a number of state rare plants (Gardner 2004). The marsh contains a number of invasive species including *Butomus umbellatus*, *Lythrum salicaria*, *Myriophyllum spicatum*, *Phragmites australis* ssp. *australis*, *Potamogeton crispus*, and *Typha angustifolia*. *Hydrocharis morsus-ranae* was local and uncommon with a few colonies along the marsh shore and additional small colonies floating in the marsh. The population was likely introduced by migrating waterfowl.

Hydrocharis morsus-ranae is considered a highly invasive non-native species. This is a very significant find as it adds another invasive, non-native species, to a long list of invasive species for Ohio's southern coastline of Lake Erie. The discovery is not surprising based on its rate of spread from its initial introduction to North America (Catling and Porebski 1995). In Ontario, it has been rapidly spreading in the lower Great Lakes of Ontario and at some sites it is now the dominant vegetation cover (Jones 2005). *Hydrocharis morsus-ranae*

grows well in quiet waters and will likely spread among the diked marshes of Ohio's southern Lake Erie coast. Control methods for this species are only by hand-pulling or mechanical harvest (Natureserve 2007).

Specimen citation: LUCAS CO.: At northwest end of large diked marsh, Cedar Point National Wildlife Refuge, SE1/4 Sec. 15, Jerusalem Twp., 7 Jul 2004, *Gardner & J. Mack 4946* (OS).

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NOTEWORTHY COLLECTION

MICHIGAN

Glyceria melicaria (Michx.) F. T. Hubbard. (Poaceae). Northeastern Mannagrass, Long Mannagrass, or Melic Mannagrass.

Previous knowledge. This species is found in swamps and wet grounds (Hitchcock and Chase 1971; Gleason and Cronquist 1991; Flora of North America Editorial Committee 2007) in portions of the eastern United States and Canada. Its distribution in the eastern United States prior to the collections reported here includes Alabama, Connecticut, Georgia, Kentucky, Maine, Maryland, Massachusetts, Mississippi, Ohio, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont, Virginia, and West Virginia (USDA NRCS 2008). In Canada, Gleason and Cronquist (1991) identify its range from Quebec to New Brunswick and Nova Scotia. Oldham et al. (1995) reported a range extension for this species in Ontario which may be the closest to this Michigan collection. Synonyms, not used in many years, include *Glyceria torreyana* Hitchc., *Panicularia torreyana* Merr. (Hitchcock and Chase 1971), *Glyceria nervata* (Flora of North America Editorial Committee 2007), and *Panicularia melicaria* (Michx.) Hitchc. (USDA NRCS 2008).

Significance. *Glyceria melicaria* is a grass previously unknown in the state of Michigan. The large population located in Oceana County which was discovered in 1997 and revisited several times over the years, is well established. Its location in a relatively undisturbed area of swampland suggests that its occurrence is not the result of a human introduction.

Diagnostic characters. A perennial graminoid, *Glyceria melicaria* displays slender, erect culms 50-100 cm tall with blades 2–7 mm wide and a distinct narrow, nodding panicle which becomes 15–25 cm long (Hitchcock and Chase 1971; Gleason and Cronquist 1991; Flora of North America Editorial Committee 2007; USDA NRCS 2008). Although reported to bloom in late spring by the National Plant Data Center (USDA NRCS 2008), tracking of this species over six years indicates that in west central Michigan (Oceana County), it blooms in early to mid-summer. *G. melicaria* can be distinguished from other small-spikeleted *Glyceria* found in Michigan (*G. grandis*, *G. striata*) in the panicle being narrow and much longer than wide, as opposed to diffuse and little longer than wide, and the ligules being less than 1 mm long, as opposed to ligules longer than 1 mm, often much longer (Hitchcock and Chase 1971; Gleason and Cronquist 1991).

Specimen citations. OCEANA CO.: semi-open lowland/swamp. Associates include *Impatiens* sp. NW 1/4 NE 1/4 Sec. 34 T14N R18W; Camp Miniwanca, 25 June 1997, *Rafaill 97-64* (Albion College, !A.A. Reznicek). Shaded lowland at edge of woods. Associates include *Arisaema triphyllum* and *Impatiens* sp. NW 1/4 NE 1/4 Sec. 34 T14N R18W; Camp Miniwanca, 13 July 2000, *Rafaill 00-20*

(Albion College, !A.A. Reznicek). Shady lowland swamp. Associates include *Betula alleghaniensis* and *Impatiens* sp. NW 1/4 NE 1/4 Sec. 34 T14N R18W; Camp Miniwanca, 7 July 2003, *Rafaill 03-122* (MICH, !A.A. Reznicek).

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COMPARISON OF LANDSCAPE AND VEGETATION METRICS BETWEEN WETLANDS IN THE NORTHERN GREAT LAKES REGION AND HIGH ELEVATION CENTRAL APPALACHIAN WETLANDS

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ABSTRACT

I surveyed 58 wetlands in northern Wisconsin and Michigan's Upper Peninsula to examine patterns in vegetation community composition. In a principal components analysis of genera-weighted values, riverine sites were distinctly different from lacustrine and palustrine sites. Site loadings of the first principal component were correlated with site pH and a weighted site index of wetland plants. Similarity among wetlands was not influenced by distance among sites, and relative species richness was not influenced by wetland area. I then compared these northern wetland results to identical vegetation surveys of 20 high elevation wetlands in northern West Virginia and western Maryland, using plant community measures as relative disturbance indicators. Comparisons of the two regions indicated that more wetland-obligate and -facultative species were present in the northern wetlands than in relicts further south, and that relative species richness of non-woody species was higher in northern wetlands. Vegetation disturbance indicators, though relatively higher in northern wetlands than in central Appalachian relicts, revealed markedly low disturbance measures in both regions. The minimal levels of disturbance indicate the potential use of both regional sets of wetlands as baseline data for future disturbance studies.

KEY WORDS: boreal wetland, disturbance, metric, relict wetland

INTRODUCTION

Boreal wetlands, specifically those in northern Wisconsin and Michigan's Upper Peninsula, may be classified into multiple communities, such as open bogs, boreal rich fens, muskegs, and northern wet forests (Epstein et al. 2002). These multiple habitat types have primarily developed in basins scoured out ca. 10 000 BCE from the last recession of glaciers (Wisconsin glaciation; Mitsch and Gosselink 2000). Though not directly affected by the last glacial event (glaciers extended south to southern Pennsylvania; Rigg and Strausbaugh 1949), wetlands with similar climate conditions and plant communities are less common but locally abundant in portions of the central Appalachian Mountains. The higher elevations experience locally cool climate, and act as a refuge for many northern plant species that migrated altitudinally as glaciers receded from the last continental glaciation (Fortney 1975; Ingham 1996; Francl et al. 2004a).

Because of the lack of glaciation in the central Appalachian region, the age and origin of these wetlands differed from their northern counterparts. Whereas northern wetlands typically began as kettle lakes, filling in from the water surface downwards to create open, floating *Sphagnum* mats, many central Ap-

palachian wetlands were originally forested wetlands (Clarkson 1993). A commonality to both regions is that extensive logging activity at the turn of the 20th century (ca. 1880–1910) drastically altered the wetlands of each region. In Michigan's Upper Peninsula, preferential logging of white pine (*Pinus strobus* L.) resulted in forests dominated by stands of hardwoods and hemlock (*Tsuga canadensis* [L.] Carr.). The emergent wetlands, scattered in depressions within the hardwoods-hemlock landscape, were not logged, although skid trails and other access roads were constructed along their borders (O'Neil 1938). Fires were fairly common through cut-over hardwood sites (O'Neil 1938).

Central Appalachian mountain wetlands originally consisted of red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea [L.] P. Mill.*), and rosebay rhododendron (*Rhododendron maximum* L.) in the canopy and subcanopy and a floor of wetland mosses atop a deep organic layer. Clearcutting efforts in these habitats exposed the rich organic soils, and subsequent fires burned and removed the organic layers. What remained were rock outcrops and isolated pockets of raised water tables (now, too wet to support tree regeneration), suitable for sustaining the present-day shrub-scrub and emergent wetlands. Hence, compared to boreal wetlands of the northern United States, most central Appalachian wetlands are geologically younger and markedly altered (more disturbed) from their natural state over a century ago (Fortney 1993).

Across the current regional landscapes, examinations of National Wetland Inventory (NWI; 1:100,000) maps reveal marked difference between the two study areas. Proportional wetland area (emergent and shrub-scrub) is greater in the studied portion of Michigan's western and central Upper Peninsula (22.8% of land area in Ironwood and Wakefield quadrangles) than in the studied areas of northern West Virginia and western Maryland (0.6% in Elkins and Kingwood quadrangles). Furthermore, when comparing both wetland area in the cited quadrangles, the number of wetlands and average wetland size is greater in this portion of Michigan for both emergent (avg. = 2.5 ha [N = 910] vs. 1.4 ha [N = 1724]) and forested (avg. = 7.4 ha [N = 8061] vs. 2.4 ha [N = 2082]) wetlands (U.S. Fish and Wildlife Service 2006). Given that larger wetland areas tend to support greater plant species richness and diversity (Smith and Haukos 2002; Ashworth et al. 2006), it is likely that, on average, the northern sites may support more species-rich plant communities than their central Appalachian counterparts.

Francl et al. (2004a) studied the vegetation communities of 20 wetland habitats in West Virginia and western Maryland, and found that plant communities were distributed along soil chemical (pH, conductivity) gradients. These patterns are not surprising, as plant communities often separate out along a chemical gradient. Indeed, pH is used to define ombrotrophic wetlands of the north (pH < 4.1), due to the unique acid-tolerant plant community they support (e.g., Core 1966, Walbridge 1994). Furthermore, wetland plant communities were grouped geographically, with sites closer to one another sharing more similar vegetative characteristics (Francl et al. 2004a). Therefore, this current project sought to reproduce the central Appalachian surveys in wetlands of northern Wisconsin and Michigan's Upper Peninsula to determine if similar trends in chemistry and geography were apparent. In duplicating the methods, the two regions could be di-

rectly compared in terms of multiple vegetative parameters and wetland indices, elucidating differences in vegetation structure between northern wetlands and central Appalachian wetlands.

In a study of headwater wetlands in the Ridge and Valley region of central Pennsylvania, Miller et al. (2006) found strong correlations between multiple vegetative parameters and anthropogenic disturbance measures. I used 12 of these plant metrics in the current study. Although raw data were not directly comparable to the Pennsylvania study, proportional vegetation measures could gauge relative disturbance levels among the three regions.

In examining the spectrum of wetland types in Michigan and Wisconsin, I predicted that the majority of palustrine sites would have wetland vegetative index values < 2.0 (an indicator by Tiner [1999] that the site is a true wetland), and clearly differ in vegetation from surveyed riverine and lacustrine sites. As was the case for central Appalachian wetlands, I expected Michigan-Wisconsin wetland species distributions would separate along a pH gradient, and that sites geographically closer to one another would be more similar in vegetation composition. I also predicted that West Virginia-Maryland wetlands would have vegetation community measures that corresponded to higher degrees of disturbance, primarily because they are less concentrated across the landscape and because they have been markedly altered from their original forested wetland state. Furthermore, I hypothesized these more southerly wetlands would have lower species richness values and exhibit higher wetland index values (i.e., less wetland-dependent vegetation) than their northern counterparts.

METHODS

Site selection and data collection

I surveyed 58 wetlands in 2003 and 2004: 32 palustrine, 14 riverine, and 12 lacustrine habitats (Figure 1, Appendix 1; hereafter, "MI-WI sites"). Forty-five sites were located at the University of Notre Dame Environmental Research Center (UNDERC) in Gogebic Co., Michigan and Vilas Co., Wisconsin; 13 sites were located within the Ottawa National Forest in Gogebic Co., Michigan (Appendix 1).

Twenty wetlands in West Virginia (Tucker, Randolph, Preston Co.) and Maryland (Garrett Co.; hereafter, "WV-MD sites") were surveyed by Francl in summer 2001 as part of a large-scale wetland characterization project (Francl et al. 2004a). Vegetation metrics gleaned from Francl et al. (2004a) and additional recent analyses of these vegetation surveys were utilized in statistical comparisons.

At MI-WI sites, I sampled vegetation in randomly-selected 10-m × 10-m plots for woody species (2–10/site, depending on wetland size and visible habitat diversity) and 1-m × 1-m subplots for herbaceous species (9/plot), following methods described in Francl et al. (2004a). Within these plots and subplots, I visually approximated percent cover for each species. If possible, plants were identified to species, and taxonomy followed the PLANTS database (USDA NRCS 2006). Voucher specimens were deposited in the Greene-Nieuwland herbarium at the University of Notre Dame, Notre Dame, IN.

Site pH was measured at all sites within 36 h in August 2004. These measures were taken with a pH probe (Oakton Instruments, Vernon Hills, IL, USA) at least 48 h after a significant rain event to avoid rainfall bias (Allan 1995). Site pH was averaged across multiple readings of standing water; if no water was visible, a soil sample (<10 cm from surface, excluding live vegetation) was collected, mixed in a 50:50 solution with DI water, and measured 30 min after initial mixing (S. Bridgham, personal communication, 2004).

All GIS analyses were performed using ArcGIS 8.3 (ESRI, Inc., Redlands, CA, USA), using

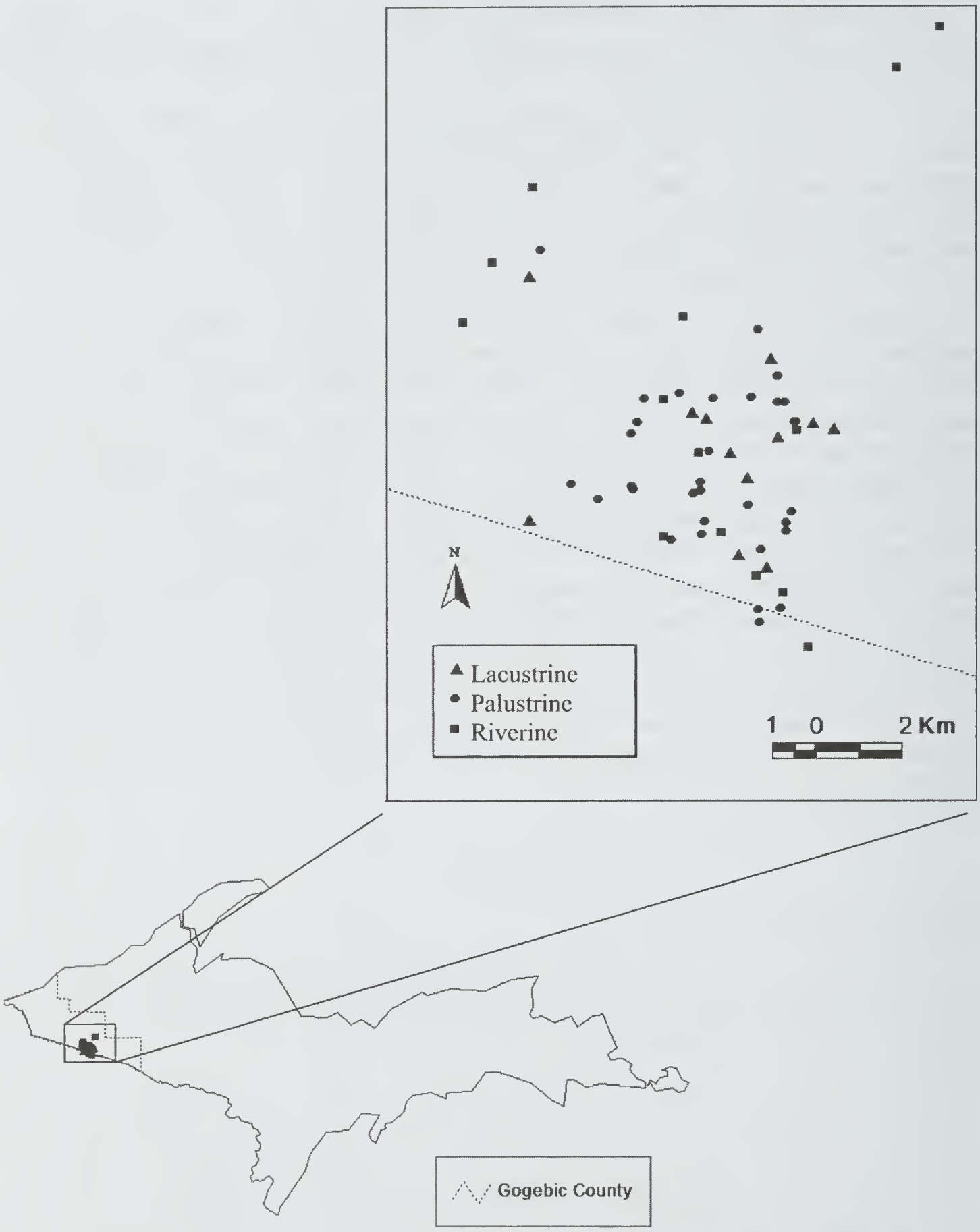

FIGURE 1. Map of 58 wetland sites surveyed in 2003–2004 in Michigan's Upper Peninsula (Gogebic Co.; border shown as dashed line) and northern Wisconsin (Vilas Co.). Inset shows site location and breakdown according to wetland types (lacustrine: triangles, palustrine: circles, riverine: squares).

datum UTM NAD27, Zone 16N. MI-WI site GPS was recorded, and straight-line distances among sites were determined from these points. For each site, I estimated proportional landuse within a 500-m buffer using a series of overlaid maps that maximized wetland recognition and accurate identification of surrounding habitats. Buffer data and road measures for the WV-MD sites were described in Francl et al.'s (2004b) GIS study. Data for MI-WI sites were assembled from existing

forest stand information (e.g., additional landuse/landcover types and road shapefiles created by the Ottawa National Forest [courtesy of B. Bogaczyk, Bessemer Ranger District, Ottawa National Forest]) and Francl's ground-truthing work at UNDERC (K. Francl, unpublished data). Road density was calculated by summing road segment lengths (m) within each 500-m buffer. Proportional habitat values were combined into four landuse categories: forest, wetland, agriculture/open, and other. Proportions for each of the first three categories, as well as road density, were separately compared between regions using Student's t-tests. Continuous wetland area also was calculated from these layers, and Pearson's correlations were used to compare area to both plot and subplot species richness for each site.

Michigan-Wisconsin intra-regional comparisons

For each MI-WI site, I calculated the importance value (I; Cox 1996) of each plant species, which equally weighed its relative dominance (estimated by percent cover) and relative frequency (proportion of plots or subplots containing the species). Vegetation was then analyzed using weighted averages for each species, where each species is assigned an appropriate ecological indicator value, ranging from one (obligate wetland species) to five (obligate upland species, Reed 1988). If Reed (1998) did not assign a value to a species (e.g., non-vascular plants), I assigned an appropriate value, based on literature review and values assigned to other closely-related species (e.g., all *Sphagnum* spp. were considered wetland-obligate species). A weighted average was calculated for each site, based on the I-value for each species and its corresponding ecological indicator value (Francl et al. 2004a; modified from Tiner 1999). The resulting weighted average ranged from one to five; weighted averages typically are < 2.0 in wetlands (Tiner 1999).

Principal components analyses (PCA) were performed using NTSYS-pc ver. 2.02i (Applied Biostatistics, Inc., Setauket, NY, USA). To best incorporate the value of plants identified to genus only (e.g., *Sphagnum* spp., some *Carex* spp., *Rubus* spp.), I examined plants at the genus level (N = 156 genera). Although this choice may limit the power of detecting within-genus differences, the same methods were utilized in Francl et al. (2004a), and consistency across studies was preferred for inter-regional comparisons.

Plot and subplot plant data, measured in proportions (*I*-values), were standardized using the default methods in NTSYS. Initially, separate principal components analyses were performed using the *I*-values for each genus for woody (plot) and herbaceous (subplot) data. However, the first principal components of woody and herbaceous analyses were strongly correlated ($r = 0.613$, $p < 0.001$). Therefore, I performed a single PCA for all vegetation data, giving equal weight to plot and subplot *I*-values. For this analysis, I calculated correlations among variables, then extracted the first three principal components from the correlation matrix. Pearson's correlations separately compared pH and weighted site indices to site projection values for each of the first three components, and a scatter diagram plotted site projection values for the first two components that explained the greatest amount of variance.

A Mantel test contrasted a matrix of geographic distances among MI-WI sites (minimum distance, meters) and a dissimilarity matrix using *I*-value genera loadings as a measure of vegetation differences across sites. Results determined if plant communities were clustered geographically.

Inter-regional comparisons

To compare vegetation surveys from MI-WI to WV-MD sites, 11 community metrics were calculated for each site, using combined plot and subplot data. Most parameters selected were significantly correlated to Miller et al.'s (2006) disturbance gradient among Pennsylvania wetlands (Table 1). Measures included proportion (relative to total number of species per site) of annuals, perennials, dicots, monocots, vascular cryptogams (ferns and fern allies), non-natives, and forbs. I calculated the number of *Carex* spp. (Cyperaceae), all sedge spp. (Cyperaceae), and native grasses (Poaceae) as a proportion of the number of forb species per site (Miller et al. 2006). The number of species with a wetland indicator status of obligate- or facultative-wetland was calculated as a proportion of the number of species with an assigned indicator value, as well (Miller et al. 2006). Student's t-tests compared values of each metric between the two regions.

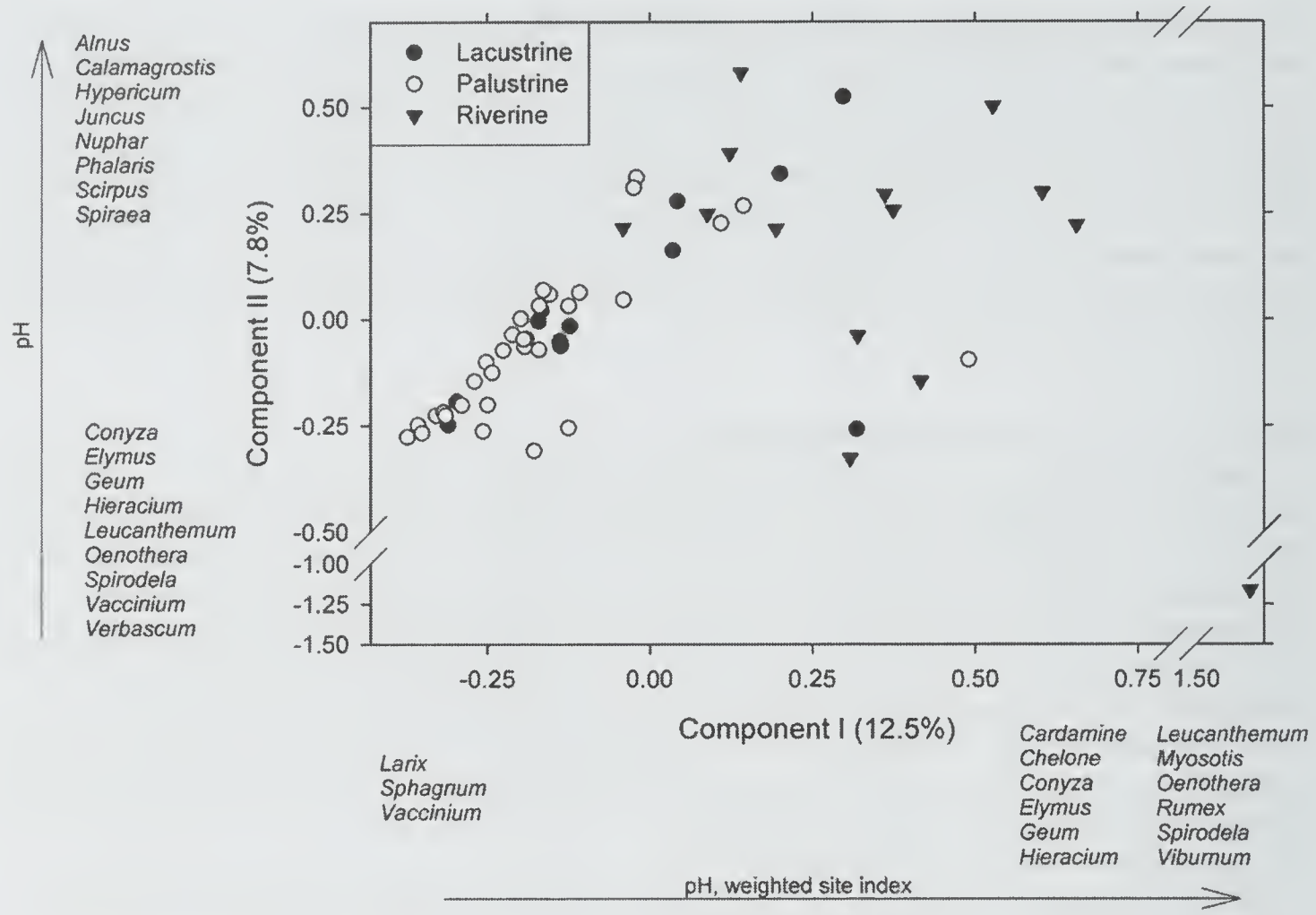

FIGURE 2. Principle components analysis of combined vegetation plot and subplot data for 58 wetlands sites in northern Wisconsin and Michigan's Upper Peninsula. Plant genera exhibiting high positive or negative loadings are listed on the appropriate axis. Significant positive correlations of site loadings with pH and weighted site index values are also indicated.

RESULTS

Michigan-Wisconsin intra-regional comparisons

In 223 plots and 2009 subplots, I documented 212 species within 156 genera and 74 families of vascular and non-vascular plants (Appendix 2). Of these plants, 118 (55.7%) were classified as wetland-obligate species and 58 (27.4%) were wetland-facultative (Appendix 2). The remaining species were identified as wetland/upland-neutral or upland categories (Appendix 2; Reed 1988). Site pH values ranged from 4.0 – 8.4 across sites (average = 5.5 ± 0.3 [95% C.I.]; Appendix 1).

Weighted index values, averaged for plot and subplot data, ranged from 1.08–2.97 (average = 1.63 ± 0.11; Appendix 1). Eleven of 12 lacustrine sites, 29 of 32 palustrine sites, and 10 of 14 riverine sites exhibited weighted index values < 2.0 (Appendix 1). Overall, I found an average of 5.6 ± 0.5 woody species per plot (range 1.3–10.0) and 5.7 ± 0.4 (range 3.5–9.9) herbaceous species per subplot. Wetland area was not influential in species richness values across palustrine and lacustrine sites (plots: $r = -0.202$, $p = 0.188$; subplots: $r = -0.124$, $p = 0.421$), and was not related to wetland index values ($r = -0.017$, $p = 0.915$).

In a PCA of the combined vegetation plot and subplot data at the genus level, the first component explained 12.5% of total character variance, and separated

out Tenderfoot Creek ERC (Gogebic Co., Michigan) from the remaining 57 sites (Figure 2). Tenderfoot Creek ERC contained several disturbance-tolerant species not restricted to wetland habitats, and additional upland species unique to this site. To a lesser extent, the remaining riverine sites also separated from lacustrine and palustrine sites on this axis. Twelve genera exhibited loadings > 0.650 on the positive end of the axis (Figure 2). Three plant genera exhibited similar high loadings on the negative end of the axis: *Larix* (eigenvalue of –0.644), *Sphagnum* (–0.761), and *Vaccinium* (–0.657), and were concentrated at more palustrine sites. The second component explained 7.8% of the variance, and again separated out most palustrine and lacustrine sites from riverine sites (Figure 2). Again, Tenderfoot Creek ERC was separated out as an extreme site; indeed, of the nine plant genera exhibiting loadings < –0.500, just two (*Vaccinium*, *Verbascum*) did not exhibit similarly high loadings documented in Component I (Figure 2). Eight genera showed loadings > 0.500 for this second component (Figure 2). The third component (not displayed) constituted 7.3% of the total character variance, and separated 3 creek sites (Tenderfoot Creek ERC loading = –0.839; Kakabika Falls = 1.070; Vernal Creek = 1.079) from the remaining sites. Plants exhibiting high positive loadings included *Abies* (0.630), *Acer* (0.601), *Betula* (0.679), *Dryopteris* (0.831), and unidentified mosses (0.768), while no plant genera exhibited negative loadings < –0.450.

A significant positive correlation was discovered between loadings of the first component and pH ($r = 0.672$, $p < 0.001$; Figure 2). A weaker trend also was discovered between pH and the second component loadings ($r = 0.359$, $p = 0.006$; Figure 2), while no relationship was discovered between pH and the third component ($r = -0.024$, $p = 0.857$). Wetland index values also were positively correlated to the first component ($r = 0.582$, $p < 0.001$) and the third component ($r = 0.681$, $p < 0.001$), but were not related to the second component's loadings ($r = 0.143$, $p = 0.285$; Figure 2).

A Mantel test indicated that geographical distance between sites relative to vegetation community dissimilarity explained just 7.9% ($r = 0.281$) of variance among sites. Statistical tests (Mantel $t = 2.599$, $p = 0.995$) revealed that this relationship was not significant.

Inter-regional comparisons

Of the original 183 plant species collected in WV-MD, 54 non-woody and 15 woody species (37.7% of all species) also were found in the MI-WI surveys. WV-MD sites, therefore, contained 114 unique species, while I discovered 143 non-overlapping species in the MI-WI surveys. Student's t-tests of vegetative community metrics revealed that MI-WI sites had a lower wetland site index, higher pH, higher species richness averages for (non-woody) subplots, and higher proportions of perennials, dicots, monocots, members of family Cyperaceae, and obligate/facultative wetland species than the WV-MD sites. The WV-MD sites had greater proportions of *Carex* spp. and cryptogams, and lower proportions of Cyperaceae representatives (Table 1). When comparing landuse-landcover metrics between regions, the MI-WI sites had a significantly higher road density, and lower proportions of forest cover (Table 1). There was a trend ($p = 0.122$) towards a higher proportion of wetland cover for the MI-WI

TABLE 1. Comparison of pH, vegetation community values, and surrounding landuse variables (average ± SD) between 58 wetlands in Michigan's Upper Peninsula and northern Wisconsin and 20 wetlands studied in West Virginia and Maryland. Results from t-tests ($p < 0.10$ in bold) compare two regional groups. Expected relationship to increasing levels of disturbance from Miller et al. (2006).

Variable	Relation to Increasing Disturbance	MI & WI	WV & MD	t	p
Site pH	—	**5.5 ± 1.2**	**4.2 ± 0.8**	**5.391**	**<0.001**
Weighted site index	—	**1.64 ± 0.41**	**2.16 ± 0.40**	**4.958**	**<0.001**
Avg. species richness (plot)	—	5.6 ± 1.8	5.7 ± 1.6	0.037	0.970
Avg. species richness (subplot)	—	**5.7 ± 1.4**	**4.7 ± 1.2**	**2.827**	**0.006**
Prop. annuals	Positive	0.016 ± 0.026	0.009 ± 0.018	0.963	0.339
Prop. perennials	Negative	**0.906 ± 0.030**	**0.830 ± 0.038**	**9.014**	**<0.001**
Prop. dicots	Positive	**0.546 ± 0.062**	**0.467 ± 0.102**	**3.234**	**0.004**
Prop. monocots	None	**0.337 ± 0.071**	**0.293 ± 0.099**	**2.143**	**0.035**
Prop. vascular cryptogams	Negative	**0.057 ± 0.042**	**0.102 ± 0.058**	**3.725**	**<0.001**
Prop. non-natives	Positive	**0.021 ± 0.033**	**0.039 ± 0.041**	**2.031**	**0.046**
Prop. forbs	Positive	**0.399 ± 0.119**	**0.232 ± 0.077**	**7.201**	**<0.001**
Prop. *Carex*	Negative	**0.321 ± 0.242**	**0.514 ± 0.350**	**2.281**	**0.031**
Prop. Cyperaceae	Negative	**0.468 ± 0.325**	**0.217 ± 0.105**	**5.160**	**<0.001**
Prop. native grasses	Negative	0.133 ± 0.092	0.127 ± 0.141	0.190	0.851
Prop. OBL, FACW plants	None	**0.719 ± 0.112**	**0.396 ± 0.116**	**11.028**	**<0.001**
Prop. forest cover (500-m radius)	Negative	**0.640 ± 0.166**	**0.765 ± 0.266**	**1.977**	**0.059**
Prop. wetland cover (500-m radius)	—	0.212 ± 0.112	0.151 ± 0.159	1.599	0.122
Prop. open/agricultural cover (500-m radius)	—	0.042 ± 0.055	0.085 ± 0.172	1.092	0.287
Road density (m road per 500-m radius)	—	**1701.9 ± 518.4**	**889.2 ± 823.8**	**4.139**	**<0.001**

sites, as well (Table 1). Of the twelve metrics I measured, MI-WI sites were rated as relatively more disturbed for five (proportions of dicots, vascular cryptogams, forbs, Carex, and forest cover [within 500-m radius]), while WV-MD sites were rated as more disturbed for three measures (proportions of perennials, non-native species, and Cyperaceae).

DISCUSSION

In examining vegetative patterns across 58 MI-WI sites, the majority (86.2%) of wetlands exhibited index values < 2.0, indicating their dominance by wetland-obligate or -facultative species. The sites that did differ markedly were riverine, typically dominated by more upland species and lacking a wide riparian area. Results from the PCA emphasized that most riverine habitats separated out clearly from remaining lacustrine and palustrine wetlands. However, eigenvalues (variance explained) were relatively low for each of the first three components, indicating overlap of species across multiple sites and that vegetation communities were not clearly distinguishable. Furthermore, the PCA was unable to separate out lacustrine sites from palustrine ones, likely because many study lakes

were bounded by bog-like acidophilic vegetation. Despite the lacustrine habitat classification, 11/12 sites had weighted values < 2.0, suggesting that wetland categories may overlap in vegetative characteristics. Other factors that could influence vegetation distribution patterns were initially examined (i.e., potential geological influences, like soil type and bedrock formation), but did not provide any obvious trends in preliminary analyses, though they have proven influential in other wetland studies (e.g., Liu et al. 2006, Whitehouse and Bayley 2005).

As predicted, MI-WI plant communities followed a pH gradient, coinciding with results of the WV-MD study (Francl et al. 2004a), as well as boreal plant studies in Canada (e.g., Girardin et al. 2001; Locky and Bayley 2006). However, I did not find a relationship between vegetative communities and physical distance from one another, like that of the WV-MD study. Perhaps seed dispersal among sites is greater in MI-WI, as sites are less isolated on the landscape (Ashworth et al. 2006; Houlahan et al. 2006).

Average species richness of non-woody vegetation was higher for MI-WI sites, as predicted. Furthermore, wetland index values were lower in MI-WI sites, indicating that wetland-dependent vegetation is more dominant at these sites. This may be a result of wetland age (Spieles 2005) and wetland density across the landscape (i.e., shorter distances for seed or spore travel among sites; Ashworth et al. 2006).

MI-WI sites showed significantly different values for five of the eight parameters that indicated higher levels of disturbance, while WV-MD sites showed evidence of greater disturbance for three parameters. One reason for this inconsistency in disturbance trends is that the range of disturbance across current study sites is more restricted than Miller et al.'s (2006) Pennsylvania sites. For example, (by visual examination of plotted data) Miller et al.'s (2006) sites exhibited scores from 0–100% for percent annuals (current study 0–9.5%), percent non-native species (current study 0–13.8%), and percent cryptogams (current study 0–15.4%). Compared to these Pennsylvania wetlands, it's likely that nearly all MI-WI and WV-MD wetlands would be quantified as low-disturbance sites. This result may be influenced by the degree in which regional wetlands in WV-MD and MI-WI are protected, as all studied sites are either owned and managed by governmental organizations (e.g., USDA Forest Service, State of West Virginia) or private conservation-minded institutions (The Nature Conservancy, University of Notre Dame). Future research might concentrate on filling in the gaps along this disturbance gradient—making the effort to locate and survey moderately or severely disturbed wetlands (if they do indeed exist).

The relative lack of disturbance across WV-MD and MI-WI sites emphasizes their ecological value across regions. Sites in both regions could serve as reference sites for future disturbance studies. Although the current study examined species richness as a proportion of survey effort (average number of species per plot or subplot), future work might better assess wetland value by conducting whole-site surveys. From these complete species lists, more precise estimates of habitat quality would be available. Indeed, several wetlands in West Virginia and Michigan have been surveyed in their entirety (e.g., Fortney 1975; Gibson 1970; Robinette 1964, K. Francl, unpublished data). Furthermore, whole-site surveys might help us to better develop accurate species-area curves for each site, and determine if there

is indeed a difference in species richness across the spectrum of wetland area. However, if our findings hold true—that wetland size does not influence species richness in these two study regions—then we might emphasize the ecological importance and continued preservation of small wetlands on the landscape.

Not surprisingly, MI-WI sites exhibited more wetland-obligate and -facultative plant community characteristics. However, this does not discount the value of central Appalachian wetlands, based on the number of species unique to the dual surveys. Future studies might stray from the NWI system employed in this project and instead develop a Floristic Quality Assessment Index (FQAI) for West Virginia and Maryland. FQAI is available in areas such as Michigan (Herman et al. 2001), Ohio (Andreas et al. 2004), and the Chicago region (Wilhelm and Masters 1995) and a work-in-progress for Wisconsin (Bernthal 2003). This index might help future researchers to better assess the degree of disturbance in each West Virginia and Maryland wetland and accurately estimate relative wetland health.

As issues of predicted climate change and continuing landuse alteration become increasingly central in mitigating the health and survival of regional plant communities, baseline data, like these surveys provide, will be increasingly useful to habitat managers.

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APPENDIX 1. Wetland sites surveyed in 2003–2004 in northern Wisconsin and Michigan's Upper Peninsula. Wetland type follows Cowardin et al. (1979) where L = lacustrine, P= palustrine, and R= riverine. Permanent open water (e.g., lakes) was not included in wetland area measurements. Area was also not calculated for riverine wetlands because of their linearity. Also recorded is weighted site index, averaged for vegetation plot and subplot data.

Site	Easting	Northing	Type	Wetland area (ha)	pH	Weighted index
Alder Fen	303 471	5 123 411	P	7.91	4.8	1.39
Beaver Bog	305 787	5 123 588	P	0.14	4.1	1.33
Beavergate	305 313	5 125 865	P	10.01	6.0	1.67
Bergner Lake	306 496	5 123 861	L	4.01	4.7	1.58
Blue Flag Bog	302 833	5 123 759	P	3.49	4.0	1.59
Bluebill Creek	301 971	5 130 555	R	—	8.4	1.27
Boggy Forest	307 894	5 123 116	P	2.11	4.0	2.03
Boomer Bog	304 270	5 123 657	P	3.10	5.1	1.51
Brown Creek	308 276	5 119 968	R	—	6.6	1.70
Bubba Bog	307 577	5 126 254	P	5.47	5.5	1.58
Buck Creek	305 771	5 124 453	R	—	5.2	1.77
Calla Bog	304 208	5 123 689	P	3.91	5.1	1.39
Castleberry Bog	307 930	5 125 185	P	1.81	4.9	1.42
Cattail Bog	304 209	5 124 913	P	0.63	4.8	1.57
Cornelia Lake	307 408	5 126 637	L	1.86	5.7	1.26
Cranberry Lake	301 897	5 122 910	L	11.24	4.5	1.33
Donut Complex	306 909	5 123 327	P	3.25	4.5	1.50
Ed's Bog	307 755	5 122 857	P	0.08	5.4	1.32
Firestone	305 974	5 124 498	P	4.78	5.1	1.77
Foggy Creek	308 019	5 124 977	R	—	5.5	2.36
Foggy Lake	308 379	5 125 151	L	8.20	5.4	1.38
Ford Bog	307 721	5 125 826	P	0.33	4.7	1.51
Forest Service Bog	307 139	5 120 800	P	1.62	5.2	1.36
Forest Swamp	307 181	5 122 245	P	1.19	4.2	1.93
Frodo Bog	307 127	5 120 864	P	1.26	4.3	1.24
Gravel Pit 2Sn Bog	304 300	5 125 177	P	7.17	5.5	1.38
Grosbeck Creek	310 313	5 133 310	R	—	6.9	1.88
Ho Bog	306 954	5 125 735	P	1.36	4.0	1.87
Holiday Creek	304 952	5 125 707	R	—	6.2	1.43
Hummingbird Lake	306 857	5 123 878	L	0.92	4.5	1.62
Jumping Mouse Bog	307 098	5 127 262	P	1.04	5.2	1.46
Kakabika Falls	311 296	5 134 232	R	—	7.3	2.95
Kickapoo Creek	307 079	5 121 642	R	—	6.6	1.23
Kickapoo Lake	307 315	5 121 828	L	17.77	7.3	1.29
Little Fen	305 788	5 124 022	P	0.16	4.4	1.60
Luke Fen	304 503	5 125 718	P	1.33	4.0	1.42
Misty Lake	308 858	5 125 004	L	1.09	5.3	1.73
Morris Lake	305 594	5 125 416	L	1.08	7.4	1.38
Muddy Field	307 758	5 122 655	P	0.28	5.1	2.46
Northgate Bog	307 548	5 125 640	P	0.23	4.2	1.49
Oz Bog	307 972	5 125 181	P	1.13	5.2	1.30
Plum / Inkpot Lake	306 694	5 122 329	L	7.92	7.5	1.21
Plum Creek	307 706	5 121 253	R	—	5.6	1.40
Plum Fen	307 627	5 121 131	P	2.92	5.0	2.69
Pomeroy Bog	302 137	5 129 103	P	18.70	4.2	1.21
Pomeroy Creek	301 047	5 128 813	R	—	7.1	1.93
Pomeroy Lake	301 871	5 128 495	L	24.76	8.0	2.16
Presque Isle River	300 376	5 127 428	R	—	7.3	1.95
Reddington Bog	306 086	5 125 712	P	1.11	5.5	1.08

APPENDIX 1. Continued.

Site	Easting	Northing	Type	Wetland area (ha)	pH	Weighted index
Riley Fen	305 498	5 123 591	P	1.40	5.0	1.33
Shire Bog	305 802	5 122 598	P	0.20	4.6	1.76
Tender Bog	305 108	5 122 480	P	0.39	4.1	1.62
Tenderfoot Creek ERC	304 892	5 124 857	R	—	7.9	2.18
Tenderfoot Creek ONF	305 392	5 127 562	R	—	6.7	1.72
Tuesday Lake	307 579	5 124 826	L	6.23	5.7	1.29
Vernal Creek	306 259	5 122 627	R	—	5.3	2.97
Ward Lake	305 904	5 125 235	L	3.40	8.3	1.76
Ziesnis Jr. Bog	305 853	5 123 112	P	0.15	4.2	1.40

APPENDIX 2. Plant species collected at 58 wetlands in northern Wisconsin and Michigan's Upper Peninsula in 2003 and 2004. The wetland indicator status (OBL = obligate wetland, FACW = facultative wetland, FAC = facultative, FACU = facultative upland, UPL = upland; +/– signs better define regional status; Reed 1988) and number of sites at which each species was collected are also listed.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Aceraceae				
Acer rubrum	L.	Red maple	FAC	40
Acer saccharinum	L.	Silver maple	FACW	1
Acer saccharum	L.	Sugar maple	FACU	8
Acer spicatum	Lam.	Mountain maple	FACU	1
Alismataceae				
Sagittaria latifolia	Willd.	Broadleaf arrowhead	OBL	18
Apiaceae				
Cicuta bulbifera	L.	Bulblet-bearing water hemlock	OBL	19
Cicuta maculata	L.	Spotted water hemlock	OBL	1
Osmorhiza claytonii	(Michx.) C.B. Clarke	Clayton's sweetroot	FACU-	2
Aquifoliaceae				
Ilex verticillata	(L.) Gray	Common winterberry	FACW+	9
Nemopanthus mucronatus	(L.) Loes.	Catberry	OBL	9
Araceae				
Calla palustris	L.	Water arum	OBL	41
Araliaceae				
Aralia nudicaulis	L.	Wild sarsaparilla	FACU	6
Asclepiadaceae				
Asclepias incarnata	L.	Swamp milkweed	OBL	16
Aspleniaceae				
Asplenium sp.	L.	Spleenwort	FACU	1
Asteraceae				
Achillea millefolium	L.	Common yarrow	FACU	4
Bidens cernua	L.	Nodding beggartick	OBL	1
Cirsium palustre	(L.) Scop.	Marsh thistle	FACW	3
Conyza canadensis	(L.) Cronq.	Canadian horseweed	FAC-	1
Doellingeria umbellata var. *umbellata*	(P. Mill.) Nees	Parasol whitetop	FACW	2
Erigeron strigosus	Muhl. ex Willd.	Prairie fleabane	FAC-	2
Eupatoriadelphus maculatus var. *maculatus*	(L.) King & H.E. Robins.	Spotted trumpetweed	OBL	10
Eupatorium perfoliatum	L.	Common boneset	FACW+	5

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Asteraceae (Continued)				
Euthamia graminifolia	(L.) Nutt.	Flat-top goldentop	FACW-	5
Hieracium kalmii	L.	Kalm's hawkweed	FACU	1
Lactuca biennis	(Moench) Fern.	Tall blue lettuce	FAC	1
Leucanthemum vulgare	Lam.	Oxeye daisy	FACU	1
Solidago canadensis	L.	Canada goldenrod	FACU	1
Solidago gigantea	Ait.	Giant goldenrod	FACW	1
Solidago hispida	Muhl. ex Willd.	Hairy goldenrod	N/A	1
Solidago speciosa	Nutt.	Showy goldenrod	N/A	2
Solidago uliginosa	Nutt.	Bog goldenrod	OBL	7
Symphyotrichum ciliolatum	(Lindl.) A.& D. Löve	Lindley's aster	N/A	1
Symphyotrichum lanceolatum var. *lanceolatum*	(Willd.) Nesom	White panicle aster	FACW	6
Balsaminaceae				
Impatiens capensis	Meerb.	Jewelweed	FACW	16
Betulaceae				
Alnus incana (L.) Moench ssp. *rugosa*	(Du Roi) Clausen	Speckled alder	OBL	34
Betula alleghaniensis	Britt.	Yellow birch	FAC	11
Betula papyrifera	Marsh.	Paper birch	FACU+	27
Betula pumila	L.	Bog birch	OBL	1
Corylus cornuta	Marsh.	Beaked hazelnut	UPL	1
Boraginaceae				
Myosotis scorpioides	L.	True forget-me-not	OBL	3
Brassicaceae				
Cardamine pensylvanica	Muhl. ex Willd.	Pennsylvania bittercress	FACW+	4
Cardamine pratensis	L.	Cuckoo flower	OBL	1
Rorippa palustris (L.) Bess. ssp. *hispida*	(Desv.) Jonsell	Hispid yellowcress	OBL	1
Bryaceae				
Bryum sp.	Hedw.	Bryum moss	OBL/FACW/ FAC	1
Cabombaceae				
Brasenia schreberi	J.F. Gmel	Watershield	OBL	5
Campanulaceae				
Campanula aparinoides	Pursh	Marsh bellflower	OBL	4
Caprifoliaceae				
Lonicera × *bella*	Zabel	Bell's honeysuckle	N/A	7
Viburnum opulus L. var. *americanum*	Ait.	American cranberrybush	FACW	1
Viburnum opulus var. *opulus*	L.	European cranberrybush	FACW	1
Caryophyllaceae				
Cerastium fontanum	Baumg.	Common mouse-ear chickweed	FACU	2
Ceratophyllaceae				
Ceratophyllum demersum	L.	Common coontail	OBL	1
Characeae				
Chara sp.	L.	Muskgrass	N/A	1
Clusiaceae				
Hypericum boreale	(Britt.) Bickn.	Northern St. Johnswort	OBL	3
Hypericum ellipticum	Hook.	Pale St. Johnswort	OBL	2
Hypericum majus	(Gray) Britt.	Large St. Johnswort	FACW	1
Hypericum punctatum	Lam.	Spotted St. Johnswort	FAC+	9
Triadenum fraseri	(Spach) Gleason	Fraser's marsh St. Johnswort	OBL	37

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Cornaceae				
Cornus canadensis	L.	Bunchberry	FAC	11
Cornus sericea	L.	Redosier dogwood	FACW	8
Cupressaceae				
Thuja occidentalis	L.	Arborvitae	FACW	5
Cyperaceae				
Carex bebbii	Olney ex Fern.	Bebb's sedge	OBL	4
Carex brunnescens	(Pers.) Poir.	Brownish sedge	FACW	14
Carex canescens	L.	Silvery sedge	OBL	6
Carex comosa	Boott	Longhair sedge	OBL	7
Carex crawfordii	Fern	Crawford's sedge	FAC+	3
Carex crinita	Lam.	Fringed sedge	FACW+	17
Carex echinata ssp. *echinata*	Murr.	Star sedge	OBL	24
Carex flava	L.	Yellow sedge	OBL	1
Carex hystericina	Muhl. ex Willd.	Bottlebrush sedge	OBL	1
Carex intumescens	Rudge	Greater bladder sedge	FACW+	5
Carex lacustris	Willd.	Hairy sedge	OBL	4
Carex lasiocarpa	Ehrh.	Woollyfruit sedge	OBL	7
Carex leptalea	Wahlenb.	Bristlystalked sedge	OBL	1
Carex magellanica Lam. ssp. *irrigua*	(Wahlenb.) Hultén	Boreal bog sedge	OBL	23
Carex oligosperma	Michx.	Fewseed sedge	OBL	13
Carex pauciflora	Lightf.	Fewflower sedge	OBL	8
Carex projecta	Mackenzie	Necklace sedge	FACW+	5
Carex pseudocyperus	L.	Cypresslike sedge	OBL	4
Carex retrorsa	Schwein.	Knotsheath sedge	OBL	11
Carex rostrata	Stokes	Beaked sedge	OBL	6
Carex scoparia	Schkuhr ex Willd.	Broom sedge	FACW	8
Carex stipata	Muhl. ex Willd.	Owlfruit sedge	OBL	10
Carex stricta	Lam.	Upright sedge	OBL	13
Carex trisperma	Dewey	Threeseeded sedge	OBL	23
Carex tuckermanii	Dewey	Tuckerman's sedge	OBL	1
Carex utriculata	Boott	Northwest Territory sedge	OBL	9
Carex vesicaria	L.	Blister sedge	OBL	1
Dulichium arundinaceum	(L.) Britt.	Threeway sedge	OBL	23
Eleocharis elliptica	Kunth	Elliptic spikerush	FACW	1
Eleocharis ovata	(Roth) Roemer & J.A. Schultes	Ovate spikerush	OBL	2
Eleocharis palustris	(L.) Roemer & J.A. Schultes	Common spikerush	OBL	3
Eriophorum tenellum	Nutt.	Fewnerved cottongrass	OBL	2
Eriophorum virginicum	L.	Tawny cottongrass	OBL	26
Rhynchospora alba	(L.) Vahl	White beaksedge	OBL	9
Schoenoplectus acutus	(Muhl. ex Bigelow) A.& D. Löve	Hardstem bulrush	OBL	1
Schoenoplectus tabernaemontani	(K.C. Gmel.) Palla	Softstem bulrush	OBL	2
Scirpus atrovirens	Willd.	Green bulrush	OBL	1
Scirpus cyperinus	(L.) Kunth	Woolgrass	OBL	35
Dennstaedtiaceae				
Pteridium aquilinum	(L.) Kuhn	Western brackenfern	FACU	9

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Droseraceae				
Drosera rotundifolia	L.	Roundleaf sundew	OBL	24
Dryopteridaceae				
Dryopteris carthusiana	(Vill.) H.P. Fuchs	Spinulose woodfern	FACW-	17
Dryopteris clintoniana	(D.C. Eat.) Dowell	Clinton's woodfern	FACW+	4
Dryopteris cristata	(L.) Gray	Crested woodfern	OBL	9
Dryopteris intermedia	(Muhl. ex Willd.) Gray	Intermediate woodfern	FAC	6
Dryopteris marginalis	(L.) Gray	Marginal woodfern	FACU	1
Onoclea sensibilis	L.	Sensitive fern	FACW	21
Equisetaceae				
Equisetum fluviatile	L.	Water horsetail	OBL	5
Equisetum sylvaticum	L.	Woodland horsetail	FACW	8
Ericaceae				
Andromeda polifolia L. var. *glaucophylla*	(Link) DC.	Bog rosemary	OBL	12
Chamaedaphne calyculata	(L.) Moench	Leatherleaf	OBL	38
Gaultheria hispidula	(L.) Muhl. ex Bigelow	Creeping snowberry	FACW	17
Gaultheria procumbens	L.	Eastern teaberry	FACU	6
Kalmia polifolia	Wangenh.	Bog laurel	OBL	18
Ledum groenlandicum	Oeder	Bog Labrador tea	OBL	29
Vaccinium macrocarpon	Ait	Cranberry	OBL	25
Vaccinium myrtilloides	Michx.	velvetleaf huckleberry	FACW-	30
Vaccinium oxycoccos	L.	Small cranberry	OBL	16
Grossulariaceae				
Ribes cynosbati	L.	Eastern prickly gooseberry	FACW	2
Ribes lacustre	(Pers.) Poir.	Prickly currant	OBL	3
Ribes triste	Pallas	Red currant	OBL	1
Hydrocharitaceae				
Elodea canadensis	Michx.	Canadian waterweed	OBL	1
Iridaceae				
Iris versicolor	L.	Blueflag iris	FACW+	27
Juncaceae				
Juncus articulatus	L.	Jointleaf rush	OBL	1
Juncus brevicaudatus	(Engelm.) Fern.	Narrowpanicle rush	OBL	7
Juncus canadensis	J. Gay ex Laharpe	Canadian rush	OBL	1
Juncus effusus	L.	Common rush	OBL	18
Juncus filiformis	L.	Thread rush	FACW	1
Juncus tenuis	Willd.	Poverty rush	FAC	2
Lamiaceae				
Clinopodium vulgare	L.	Wild basil	FACU	2
Galeopsis tetrahit	L.	Brittlestem hempnettle	FACU	4
Lycopus americanus	Muhl. ex W. Bart.	American water horehound	OBL	3
Lycopus uniflorus	Michx.	Northern bugleweed	OBL	4
Mentha arvensis	L.	Wild mint	FACW	5
Prunella vulgaris	L.	Common selfheal	FAC	1
Scutellaria galericulata	L.	Marsh scullcap	OBL	13
Scutellaria lateriflora	L.	Blue skullcap	OBL	13

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Lemnaceae				
Lemna minor	L.	Common duckweed	OBL	11
Spirodela polyrhiza	(L.) Schleiden	Giant duckweed	FACW	1
Lentibulariaceae				
Utricularia macrorhiza	Le Conte	Common bladderwort	OBL	4
Liliaceae				
Clintonia borealis	(Ait.) Raf.	Bluebead	FAC+	17
Maianthemum canadense	Desf.	Canada mayflower	FAC	26
Maianthemum racemosum	(L.) Link	Feathery false lily of the valley	FACU	1
Maianthemum trifolia	(L.) Sloboda	Threeleaf false lily of the valley	OBL	22
Polygonatum pubescens	(Willd.) Pursh	Hairy Solomon's seal	UPL	1
Trillium cernuum	L.	Whip-poor-will flower	FAC	2
Lycopodiaceae				
Lycopodium annotinum	L.	Stiff clubmoss	FAC	1
Lycopodium clavatum	L.	Running clubmoss	FAC	2
Lycopodium inundata	(L.) Holub	Inundated clubmoss	OBL	4
Lycopodium obscurum	L.	Rare clubmoss	FACU	5
Menyanthaceae				
Menyanthes trifoliata	L.	Buckbean	OBL	8
Monotropaceae				
Monotropa uniflora	L.	Indianpipe	FACU	1
Myricaceae				
Myrica gale	L.	Sweetgale	OBL	4
Nymphaeaceae				
Nuphar lutea	(L.) Sm.	Yellow pond-lily	OBL	7
Nymphaea odorata	Ait.	American white waterlily	OBL	3
Oleaceae				
Fraxinus nigra	Marsh.	Black ash	FACW+	4
Fraxinus pennsylvanica	Marsh.	Green ash	FACW	1
Onagraceae				
Circaea alpina	L.	Small enchanter's nightshade	FACW	2
Epilobium ciliatum	Raf.	Fringed willowherb	FACU	2
Epilobium leptophyllum	Raf.	Bog willowherb	OBL	17
Ludwigia palustris	(L.) Ell.	Marsh seedbox	OBL	3
Oenothera biennis	L.	Common evening-primrose	FACU	1
Ophioglossaceae				
Botrychium multifidum	(Gmel.) Trev.	Leathery grapefern	FACU	1
Botrychium virginianum	(L.) Sw.	Rattlesnake fern	FACU	1
Orchidaceae				
Cypripedium acaule	Ait.	Moccasin flower	FACW	1
Platanthera lacera	(Michx.) G. Don	Green fringed orchid	FACW	1
Pogonia ophioglossoides	(L.) Ker-Gawl.	Snakemouth orchid	OBL	3
Osmundaceae				
Osmunda cinnamomea	L.	Cinnamon fern	FACW	30
Osmunda claytoniana	L.	Interrupted fern	FAC+	1
Osmunda regalis	L.	Royal fern	OBL	5
Oxalidaceae				
Oxalis montana	Raf.	Mountain woodsorrel	FACU	5
Pinaceae				
Abies balsamea	(L.) P. Mill.	Balsam fir	FACW	18
Larix laricina	(Du Roi) K. Koch	Larch, tamarack	FACW	33

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Pinaceae (continued)				
Picea glauca	(Moench) Voss	White spruce	FACU	14
Picea mariana	(P. Mill.) B.S.P.	Black spruce	FACW	37
Pinus resinosa	Soland.	Red pine	FACU	3
Pinus strobus	L.	Eastern white pine	FACU	10
Tsuga canadensis	(L.) Carr.	Eastern hemlock	FACU	3
Poaceae				
Agrostis gigantea	Roth	Redtop	FACW	2
Agrostis hyemalis	(Walt.) B.S.P.	Winter bentgrass	FAC-	22
Agrostis perennans	(Walt.) Tuckerman	Upland bentgrass	FAC-	9
Anthoxanthum odoratum	L.	Sweet vernalgrass	FACU	1
Brachyelytrum erectum	(Schreb. ex Spreng.) Beauv.	Bearded shorthusk	?	6
Bromus ciliatus	L.	Fringed brome	FACW	3
Calamagrostis canadensis	(Michx.) Beauv.	Bluejoint grass	OBL	41
Cinna latifolia	(Trev. ex Goepp.) Griseb.	Drooping woodreed	FACW+	3
Elymus trachycaulus	(Link) Gould ex Shinners	Slender wheatgrass	FAC	1
Glyceria canadensis	(Michx.) Trin.	Rattlesnake-mannagrass	OBL	24
Glyceria grandis	S. Wats.	American mannagrass	OBL	4
Glyceria striata	(Lam.) A.S. Hitchc.	Fowl mannagrass	OBL	4
Leersia oryzoides	(L.) Sw.	Rice cutgrass	OBL	5
Phalaris arundinacea	L.	Reed canarygrass	FACW+	6
Phleum pratense	L.	Timothy	FACU	2
Poa palustris	L.	Fowl bluegrass	FACW+	4
Polygonaceae				
Polygonum amphibium	L.	Water knotweed	OBL	4
Polygonum convolvulus	L.	Black bindweed	FAC-	1
Polygonum hydropiperoides	Michx.	Swamp smartweed	OBL	1
Polygonum lapathifolium	L.	Curlytop knotweed	FACW+	2
Polygonum punctatum	Ell.	Dotted smartweed	OBL	4
Polygonum sagittatum	L.	Arrowleaf tearthumb	OBL	13
Rumex acetosella	L.	Common sheep sorrel	FAC	2
Rumex orbiculatus	Gray	Greater water dock	OBL	4
Polypodiaceae				
Polypodium virginianum	L.	Rock polypody	N/A	1
Polytrichaceae				
Polytrichum sp.	Hedw.	Polytrichum moss	N/A	34
Pontederiaceae				
Pontederia cordata	L.	Pickerelweed	OBL	3
Potomogetonaceae				
Potamogeton natans	L.	Floatingleaf pondweed	OBL	3
Primulaceae				
Lysimachia terrestris	(L.) B.S.P.	Earth loosestrife	OBL	8
Lysimachia thyrsiflora	L.	Tufted loosestrife	OBL	5
Trientalis borealis	Raf.	Starflower	FAC+	2
Pyrolaceae				
Moneses uniflora	(L.) A. Gray	Single delight	FAC	1
Pyrola chlorantha	Sw.	Greenflowered wintergreen	FACU	1

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Ranunculaceae				
Caltha palustris	L.	Marshmarigold	OBL	2
Clematis virginiana	L.	Devil's darning needles	FAC	3
Coptis trifolia	(L.) Salisb.	Threeleaf goldthread	FACW	14
Ranunculus pensylvanicus	L.f.	Pennsylvania buttercup	OBL	5
Ranunculus recurvatus	Poir.	Blisterwort	FACW	1
Thalictrum dioicum	L.	Early meadow-rue	FACU+	9
Rosaceae				
Amelanchier laevis	Wieg.	Allegheny serviceberry	FAC	2
Comarum palustre	L.	Purple marshlocks	OBL	17
Geum macrophyllum	Willd.	Largeleaf avens	FACW+	1
Photinia melanocarpa	(Michx.) Robertson & Phipps	Black chokeberry	FACW-	19
Potentilla norvegica	L.	Norwegian cinquefoil	FAC	4
Prunus nigra	Ait.	Canadian plum	FACU-	2
Prunus serotina	Ehrh.	Black cherry	FACU	22
Prunus virginiana	L.	Chokecherry	FAC-	3
Rubus sp.	L.	Blackberry	FAC-	26
Sorbus americana	(L.) Sudw.	American mountain ash	FAC+	1
Spiraea alba	DuRoi	White meadowsweet	FACW+	19
Spiraea tomentosa	L.	Steeplebush	FACW+	2
Rubiaceae				
Galium asprellum	Michx.	Rough bedstraw	OBL	10
Galium tinctorium	L.	Stiff march bedstraw	OBL	25
Galium trifidum	L.	Threepetal bedstraw	FACW+	11
Galium triflorum	Michx.	Fragrant bedstraw	FACU+	4
Salicaceae				
Populus tremuloides	Michx.	Quaking aspen	FAC	2
Salix bebbiana	Sarg.	Bebb willow	FACW+	2
Salix eriocephala	Michx.	Missouri River willow	FACW	1
Salix interior	Rowlee	Sandbar willow	OBL	5
Salix pedicellaris	Pursh	Bog willow	OBL	7
Sarraceniaceae				
Sarracenia purpurea	L.	Purple pitcherplant	OBL	13
Scheuchzeriaceae				
Scheuchzeria palustris	L.	Rannoch-rush	OBL	9
Scrophulariaceae				
Chelone glabra	L.	Turtlehead	OBL	8
Mimulus ringens	L.	Allegheny monkeyflower	OBL	8
Verbascum thapsus	L.	Common mullein	UPL	1
Veronica officinalis	L.	Common gypsyweed	UPL	3
Solanaceae				
Solanum dulcamara	L.	Climbing nightshade	FAC	5
Sparganiaceae				
Sparganium americanum	Nutt.	American bur-reed	OBL	2
Sparganium erectum L. ssp. *stoloniferum*	(Graebn.) Hara	Bur-reed	OBL	9
Sparganium eurycarpum	Engelm. ex Gray	Broadfruit bur-reed	OBL	1
Sphagnaceae				
Sphagnum sp.	L.	Sphagnum moss	OBL	40
Splachnaceae				
Splachnum ampullaceum	Hedw.	Small capsule dung moss	OBL	1

APPENDIX 2. Continued.

Scientific name	Author	Wetland Common name	Indicator	No. sites
Thelypteridaceae				
Phegopteris connectilis	(Michx.) Watt	Long beechfern	N/A	5
Thelypteris palustris Schott var. *pubescens*	(Lawson) Fern.	Eastern marsh fern	?	1
Typhaceae				
Typha latifolia	L.	Common cattail	OBL	20
Urticaceae				
Urtica dioica	L.	Stinging nettle	FACW	5
Verbenaceae				
Verbena hastata	L.	Swamp verbena	FACW+	4
Violaceae				
Viola macloskeyi	Lloyd	Small white violet	OBL	1
Viola renifolia	Gray	White violet	FACW	1
Viola rotundifolia	Michx.	Roundleaf yellow violet	FAC	3
Viola sororia	Willd.	Common blue violet	FAC-	
Vitaceae				
Parthenocissus inserta	(Kerner) Fritsch	Virginia creeper	FAC-	4

A NEW LECTOTYPIFICATION OF THE NAME *MEDEOLA VIRGINIANA* L. (LILIACEAE)

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ABSTRACT

The specimen previously designated the lectotype of the name *Medeola virginiana* L. actually represents *Asclepias quadrifolia* Jacq. and thus is significantly at variance with the protologue. Another element of Linnaeus's original material is compatible with the protologue as well as with historic and current usage. The latter specimen is designated the new lectotype, superseding the earlier choice and stabilizing the nomenclature of the species.

The name *Medeola virginiana* L., published by Linnaeus (1753) in *Species Plantarum*, ed. 1, has consistently been applied to a liliaceous species commonly known as Indian cucumber-root, which is native to much of eastern North America (Utech 2002). This species has been accepted as the type species of the genus name *Medeola* L. (Jarvis et al. 1993; Jarvis 2007), following its designation by Hitchcock and Green (1929). Although Linnaeus (1753) included two other species in *Medeola*, one Neotropical and one African, the genus has for many years been restricted to the one species *M. virginiana*.

The *International Code of Botanical Nomenclature* (McNeill et al. 2006), Art. 13.4, states that genus names first used by Linnaeus (1753) in *Species Plantarum*, ed. 1, are to be associated with the first subsequent descriptions given under those names in the fifth edition of his *Genera Plantarum*. In *Genera Plantarum*, ed. 5, Linnaeus (1754) placed *Medeola* in the Linnaean class *Hexandria Trigynia* (six stamens, three carpels), and described the genus as having a perianth of six equal parts, six stamens, three recurved stigmas, and a trilocular, baccate fruit. He distinguished *M. virginiana* from the two tropical species by its whorled leaves and non-spiny stems.

In the synonymy of the name *M. virginiana*, Linnaeus cited two phrase-names from earlier publications. The word *Medeola* had been included only in the first of these, Gronovius's (1739) *Flora Virginica*, ed. 1, in which the cucumber-root was named *Medeola foliis stellatis, fructu baccato*. Gronovius quoted descriptive information from a manuscript by John Clayton, who had become acquainted with this species in Virginia and had sent a specimen of it to Mark Catesby in England, from whom it was acquired by Gronovius. That specimen, now in the John Clayton Herbarium at BM (cited below as the new lectotype; image at <http://internt.nhm.ac.uk/resources/research-curation/projects/clayton-herbarium/lgimages/BM000032590.JPG>, accessed 6 Feb 2008), clearly represents the liliaceous species to which the name *M. virginiana* is now applied. An-

notations by Gronovius, one of which includes the same wording that he used in *Flora Virginica*, identify this specimen as the *Medeola* described in that work. Reveal (1983) has recognized this specimen as thereby having been "indirectly reported in Linnaeus' first edition of *Species Plantarum*." It has been annotated "Syntype specimen of *Medeola virginiana* L." The latter annotation is anonymous and undated, but antedates the current Linnaean Plant Name Typification Project. (Standard symbols for herbaria follow Holmgren and Holmgren 1998 et seq.)

The other name cited by Linnaeus (1753) was from Plukenet's *Almagestum Botanicum* (1696, p. 401), in which the species was designated *Lilium s*[*ive*] *Martagon pusillum Virginianum, floribus minutissime herbaceis*. This phrase-name was also cited by Gronovius (1739). Plukenet quoted it from, and attributed it to, a catalogue of Virginia plants by John Banister, which had been published in vol. 2 of Ray's (1688) *Historia Plantarum*. Banister's drawing of the plant to which he gave this phrase-name (his no. 82, original at BM; reproduced in Ewan and Ewan 1970, p. 15 of Banister's drawings, fig. 8), clearly represents the liliaceous cucumber-root.

Plukenet also cited a figure alleged to represent this species in his *Phytographia* (1691, plate CCCXXVIII, fig. 4). This figure, from a drawing by John Collins, is not adequate for positive identification. As noted by Ewan and Ewan (1970, p. 209), it does not correspond closely to Banister's drawing, differing conspicuously in the numbers of leaves per whorl and in the depiction of the venation of the leaves, as well as in details of the flowers, which are shown as having five stamens each. A plant of a different species may have been used as a model. Because the phrase-name was of Banister's authorship, his own clearly identifiable drawing, rather than this second figure, indicates the identity of the plant he thus named.

In designating a lectotype for the name *Medeola virginiana*, Reveal (in Jarvis et al. 1993) chose neither Clayton's specimen nor Banister's drawing but instead selected a specimen from Linnaeus's herbarium that had been collected by Pehr Kalm (Herb. Linn. 468.1, LINN; image at <http://www.linnean-online.org/4158/>, accessed 6 Feb 2008). Linnaeus did not mention Kalm in connection with *Medeola virginiana*, but his annotations "*virginica*" [sic] and "2" indicate that he probably did identify this specimen as that species. The specimen is in the *Medeola* genus file in the Linnaean herbarium, and *M. virginiana* is species no. 2 under *Medeola* in *Species Plantarum*, eds. 1. Although Linnaeus had acquired Kalm's specimens of North American plants prior to writing *Species Plantarum*, ed. 1, there is no indication as to whether he thus identified this specimen before or after that work was published.

The Kalm specimen currently designated the lectotype is actually a specimen of the four-leaved milkweed, *Asclepias quadrifolia* Jacq. (Asclepiadaceae), and had been identified and annotated as *Asclepias quadrifolia* by J.E. Smith. (Authorship of annotations is attributed in accord with the Web site of the Linnean Society of London, cited above). This specimen has pentamerous sepals, petals, and stamens, as is usual in *A. quadrifolia*. It is, therefore, in conflict with the generic characters given by Linnaeus (1754) for *Medeola*, including its placement in the *Hexandria Trigynia*. In equating his *M. virginiana* with Gronovius's

Medeola, Linnaeus implicitly accepted Clayton's description of the species as having a hexapetalous flower, with a purple style composed of three long filaments [actually three stigmas], and Gronovius's further description of its leaves as being in whorls of six or seven (as they are, respectively, in the two plants in Clayton's collection) and its fruit as being baccate. None of the foregoing is compatible with *A. quadrifolia*, nor, considering the conspicuously pinnate leaf venation of the milkweed, is Banister's interpretation of his plant as "*Lilium sive Martagon*." All of this descriptive material, and the placement of the genus in the *Hexandria Trigynia*, is in accord with the morphology of the cucumber-root. It does not appear that *A. quadrifolia* was significant in the formation of Linnaeus's concept of the genus *Medeola* or the species *M. virginiana* or in his preparation of the descriptions.

The specimen in the Clayton herbarium at BM can be considered a part of Linnaeus's "original material" of *M. virginiana*. Like the other specimens in that assemblage, it is from the herbarium of J.F. Gronovius, much of which was studied by Linnaeus prior to the publication of *Species Plantarum*, ed. 1, and from which the lectotypes of many Linnaean plant names have been selected (Stearn 1957). With *Medeola* having been described toward the beginning of *Flora Virginica*, in the pages presumably earliest written, it is especially likely that this specimen was seen by Linnaeus when he was working with Gronovius on that publication. Wording from *Flora Virginica*, quoted by Linnaeus in *Species Plantarum*, was based on this specimen. The morphology of the cucumber-root, including this specimen, is compatible with the protologue and the synonymy. The specimen in the Clayton herbarium cited below, therefore, is here designated the lectotype of the name *Medeola virginiana*, superseding the earlier choice by Reveal, in accord with the provisions of Art. 9.13 of the *International Code of Botanical Nomenclature*. This designation is consistent with traditional and current usage of the name. This action also stabilizes the typification of the subfamily name *Medeoloideae* (Benth.) M.N. Tamura and the family name *Medeolaceae* (S. Watson) Takht., and permits the continued use of the long-established name *Asclepias quadrifolia* for the four-leaved milkweed.

Medeola virginiana L., Sp. Pl. 1: 339. 1753. Lectotype, designated here: U.S.A.: Virginia: *Clayton 22* (BM No. 000032590).

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FRAXINUS IN A GREAT LAKES URBAN STREET TREE COMMUNITY, KALAMAZOO, MICHIGAN

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ABSTRACT

Biodiversity is of increasing concern in urban systems because it impacts both sustainability of the environment and perception of aesthetics within an urban area . The recent spread of the emerald ash borer and its impact on the genus *Fraxinus* in the Great Lakes region has increased local concern for health of urban ecosystems. In this study we examine an urban street tree dataset for Kalamazoo, Michigan using richness, diversity, and evenness metrics. Hierarchical cluster analysis results indicate five types of tree communities in Kalamazoo's neighborhoods. *Fraxinus pennsylvanica* is a dominant species in nearly every neighborhood, making up between 2 and 6 percent of individuals. Northside neighborhood is unique, with the lowest number of dominant species and lowest species richness in the city. Northside also has the highest percentage of *F. pennsylvanica* in the city. These characteristics make Northside especially vulnerable to the emerald ash borer. Because Northside also has the lowest socio-economic status of Kalamazoo's neighborhoods, assistance should be given to residents for replanting purposes if the overall tree diversity of the city is to be maintained or increased.

INTRODUCTION

The study of street trees and their role in the ecology of a cityscape has become a topic of increased discussion in the field of biogeography. Roadside tree species contribute to the overall community diversity and biomass in urban systems (Jim 1999; Savard et al. 2000; Chen & Jim 2003) while providing a historical record of landscape zonation with regard to past land use and urban development (Clare & Bunce 2006). Particular heritage specimens or cohorts of heritage trees may have additional religious, spiritual, symbolic, or other emotional value to a community (Jim 2004).

Similar to the epidemics of chestnut blight and Dutch elm disease in the 20th century, emerald ash borer (*Agrilus planipennis* Fairmaire) is currently causing the widespread removal of a common tree species from urban forests in the Great Lakes region of the United States. Emerald ash borer (EAB) is an invasive species in the U.S. that was first detected in 2002 in southeast Michigan. EAB larvae feed on the inner bark of ash trees (genus *Fraxinus*), interfering with the transport of water and nutrients within the tree (Haack et al. 2002; Poland & McCullough 2006). Both green ash (*F. pennsylvanica* Marsh.) and white ash (*F. americana* L.) have been popular street trees in cities throughout the U.S. (MacFarlane & Meyer 2005; Poland & McCullough 2006). The EAB infestation has spread to include more than 40,000 square miles (10,360,000 hectares) in

Michigan, Ohio, Indiana, Illinois, Maryland, Pennsylvania, West Virginia, and Ontario and more than 20 million ash trees are estimated to have been killed in the core area of the infestation (Poland 2007; USDA et al. 2008). Quarantine on movement of wood and nursery stock has slowed but not stopped the spread of the EAB (Muirhead et al. 2006).

Emerald ash borer has recently been found in Kalamazoo, Michigan and is expected to cause the removal of the ash trees within the city as the infestation spreads (MSU Extension, Public Meeting, 2006). The city of Kalamazoo is the largest city in Southwest Michigan and the county seat of Kalamazoo County. It is approximately halfway between Detroit and Chicago. Kalamazoo had a population of 77,145 as of the 2000 Census and an area of 25.18 square miles (65.22 square kilometers) (U.S. Census Bureau 2000). The city lies on the Kalamazoo River, but much of the city is west of the river on the rolling plains of the Kalamazoo moraine. The soils of the city are characterized by deep well-drained loams (USDA 1979). The city's climate is moderated by the "lake effect" from Lake Michigan 35 miles to the west with milder summer and winter extremes, and enhanced snowfall. The average yearly precipitation is 37″, including 70″ of snowfall (Kalamazoo County Convention and Visitor's Bureau 2008).

The purpose of this paper is to characterize an urban street tree community in the Great Lakes region. While the flora of Kalamazoo County has been well cataloged (Hanes & Hanes 1947; McKenna 2004), we are focusing specifically on the City of Kalamazoo. The species composition, neighborhood patterns, and biodiversity of the street trees maintained by the city of Kalamazoo, Michigan are examined. Trees maintained by the city, or street trees, are those trees that are planted in the city's easement between the sidewalk and the street. The city is responsible for pruning and hazard maintenance of these trees, but recent budget cuts limit the amount of resources available for this work. We examine the importance of *Fraxinus pennsylvanica* and *F. americana* within the city's street tree population and the probable impacts of emerald ash borer. Removal of ash species and decisions regarding replacement planting and city budget allocations for such work will have implications with regards to urban biodiversity and regional susceptibility to further epidemics.

METHODS

For the 18 neighborhoods in Kalamazoo for which street trees are actively maintained by the city, various diversity and evenness metrics were calculated. The Kalamazoo Street Tree Inventory was carried out under contract by the Davey Tree Expert Company, an urban forestry consulting division of Davey Resource Group that does GIS-based public tree inventories. Four certified arborists were responsible for tree inventory and identification. The Kalamazoo Street Tree Inventory as completed in 2002 was used without modification for this research.

Dominant and abundant species were identified for the city of Kalamazoo and examined spatially. Dominant species are those species contributing greater than 2 percent of individual trees in an area, while abundant species contribute less than 2 percent but greater than 1 percent of individual trees (Jim 2004). Species richness, or the number of species represented in an area, was compared with size of tree population and size of neighborhood. Shannon's diversity index was used to describe the distribution of individuals across species and Shannon's equitability index was used as a metric of evenness in those distributions. Each of these metrics is common in biogeography and

TABLE 1. Dominant and abundant species of street trees in the city of Kalamazoo, Michigan.

	Individuals	% of Total
Dominant[x] Species		
Acer platanoides (Norway maple)	5807	22.3
Acer saccharinum (Silver maple)	3653	14.0
Acer saccharum (Sugar maple)	2287	8.8
Gleditsia triacanthos (Honey locust)	1631	6.3
Acer rubrum (Red maple)	1181	4.5
Platanus × *acerifolia* (London plane tree)	1033	4.0
Fraxinus pennsylvanica (Green ash)	994	3.8
Malus spp.[y] (Apple spp.)	952	3.7
Pyrus calleryana (Callery pear)	669	2.6
Ulmus pumila (Siberian elm)	621	2.4
Tilia cordata (Small-leaved linden)	558	2.1
Abundant[z] Species		
Picea pungens (Blue spruce)	506	1.9
Quercus rubra (Northern red oak)	401	1.5
Prunus serrulata (Japanese cherry)	294	1.1
Quercus palustris (Pin oak)	283	1.1
Juglans nigra (Black walnut)	278	1.1

[x] Dominant species are those comprising more than 2% of total individuals.
[y] The genus *Malus* was not subdivided in the database.
[z] Abundant species are those comprising 1–2% of total individuals.

treescape studies (Chen and Jim 2003; MacDonald 2003). Finally, the prevalence of *Fraxinus* species was compared among neighborhoods.

Hierarchical cluster analysis (SPSS, SPSS Inc.) was used to group similar neighborhoods using a standardized set of parameters. Neighborhood values for dominant species, species richness, species diversity, equitability, percentage of population *F. pennsylvanica*, and percentage of population *F. americana* were standardized on a scale of 0–1, where the zero value was assigned to the neighborhood with the lowest value and one was assigned to the neighborhood with the highest value. The remaining neighborhoods were assigned values according to their relationship to the highest and lowest neighborhood values. The standardization allowed neighborhoods to be clustered based upon their relative similarity in a series of parameters with very different initial ranges in value.

RESULTS

Kalamazoo's urban street tree community is composed of approximately 112 tree species (Appendix A). More than 80 percent of the 26,046 individuals belong to 11 dominant and five abundant species (Table 1). Fifty percent of individuals belong to the single genus *Acer,* which is represented by ten species. These include four dominants, *A. platanoides* L. (Norway maple), *A. saccharinum* L. (silver maple), *A. saccharum* Marsh. (sugar maple), *A. rubrum* L. (red maple), and several minor species, *A. negundo* L. (box elder), *A. pseudoplatanus* L. (sycamore maple), *A. palmatum* Thumb. (Japanese maple), *A. griseum* (Franch.) Pax (paperbark maple), *A. ginnala* Maxim. (Amur maple), and *A. campestre* L. (hedge maple). The genus *Fraxinus* comprises 4.5 percent of the city's individual street trees and is represented by three species, the dominant *F.*

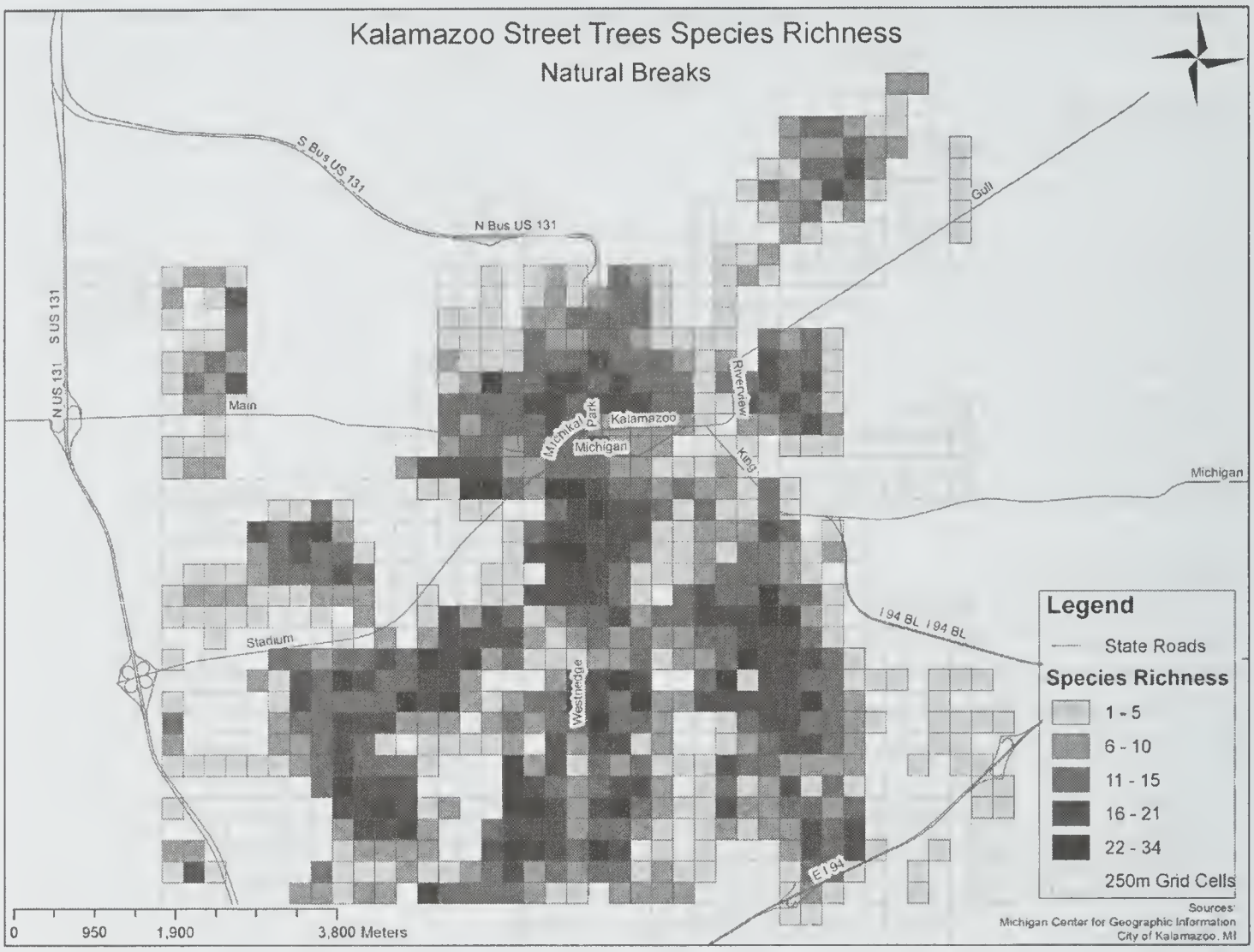

FIGURE 1. Species richness of street trees maintained by the city of Kalamazoo, Michigan.

pennsylvanica (green ash) and two minor species, *F. americana* (white ash) and *F. nigra* Marsh. (black ash).

Street tree species richness within the city is shown in Figure 1. Areas of relatively high species richness are clustered throughout the city, most apparently in large neighborhood areas south of the city center. By contrast ash trees are most common in the lower richness central city districts and southward along the Westnedge Road corridor (Figure 2). The 18 neighborhoods in Kalamazoo for which street trees are actively maintained by the city vary in size and tree diversity (Table 2, Figure 3). Milwood is by far the largest neighborhood at just over 12 km^2. Edison, South Westnedge, Oakland/Winchell, Burke Acres and Northside are also relatively large, each over 4 km^2. While these large neighborhoods do have the most individual trees, the smaller neighborhoods of Oakwood, Stuart and Vine have the highest tree densities.

Density of city street trees ranges from 148 (Knollwood) to 1054 (Oakwood) trees per km^2. Total number of species per neighborhood range from 31 (Stuart) to 87 (Edison), and the number of dominant species range from 8 (Northside) to 14 (South Westnedge). In every neighborhood except South Westnedge, *F. pennsylvanica* is a dominant species. *F. americana* is much less prevalent and is not dominant in any neighborhood, but is considered an abundant species in five of the neighborhoods. Neighborhood diversity ranges from 3.454 in Stuart to 4.992

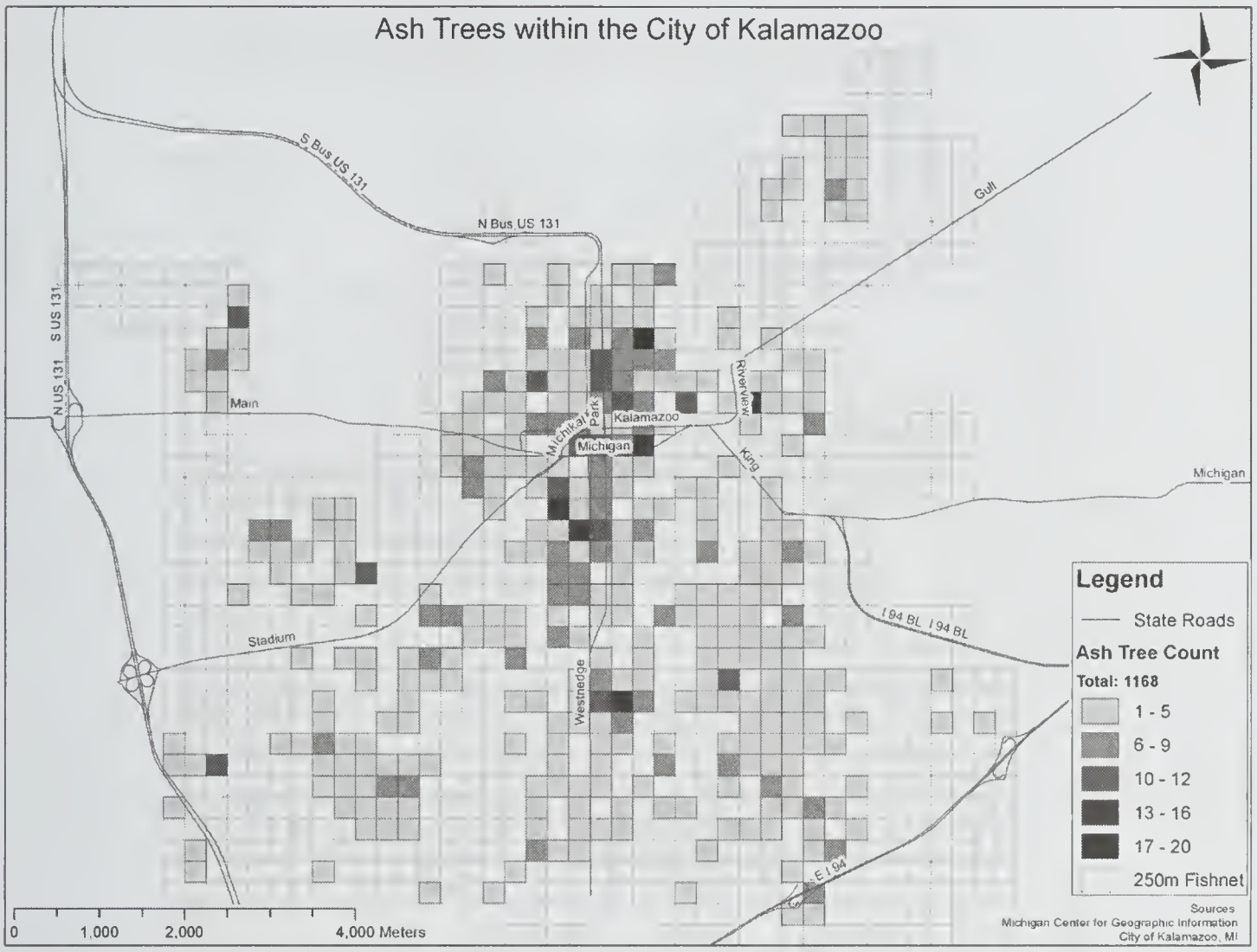

FIGURE 2. Ash trees (*Fraxinus sp.*) maintained as street trees by the city of Kalamazoo, Michigan.

in South Westnedge. Equitability, or the equalness of the distribution between species, is highest at 1.143 in Knollwood and lowest at 0.916 in Edison.

Hierarchical cluster analysis results indicate five distinct tree community types in the city of Kalamazoo (Figure 3). Northside neighborhood is unique and does not cluster with any other neighborhoods. It has both the lowest number of dominant species and lowest species richness, and subsequently has very low diversity and equitability. Northside is of interest botanically because it contains the highest percentage and by far the greatest number of *F. pennsylvanica* in the city.

The neighborhood cluster including Edison, Milwood, Oakwood, Eastside, and West Douglas are similar to Northside in that they have low richness values. These neighborhoods also have low to moderate species richness, diversity, equitability and number of dominant species. They also have low numbers of *F. pennsylvanica*, but have the largest *F. americana* populations. This cluster is the largest in area, making up more than 30 percent of the city's area.

Burke Acres, Westnedge, Central Business, Vine, West Main Hill, Westwood and Arcadia make up the cluster including the largest number of neighborhoods. While *F. pennsylvanica* is a dominant in each of these neighborhoods, *F. americana* is present only in low numbers. While not the largest neighborhoods, the number of dominant species, diversity and equitability are near the city average at these locations.

The remaining two community types contain only two neighborhoods each,

TABLE 2. Neighborhood characteristics of Kalamazoo, Michigan's street tree community.

	Area sq.km.	# Trees N	Density	Richness S	Domin. Species	Shannon Diversity	Equit.	*F. pennysylvanica* N	*F. pennysylvanica* Rank	*F. pennysylvanica* %	*F. americana* N	*F. americana* Rank	*F. americana* %
Arcadia	2.49	795	320	49	12	4.005	1.029	26	7	3.27%	1	41	0.13%
Burke Acres	4.76	1062	223	56	10	4.065	1.010	40	8	3.77%	4	26	0.38%
Central Business	1.24	951	766	37	10	3.765	1.043	61	5	6.41%	3	24	0.32%
Eastside	2.43	1023	420	56	9	4.090	1.016	33	7	3.23%	12	15	1.17%
Edison	7.20	3278	455	87	10	4.092	0.916	90	9	2.75%	26	19	0.79%
Knollwood	1.95	288	148	39	12	4.189	1.143	7	12	2.43%	3	16	1.04%
Milwood	12.49	3114	249	86	11	4.058	0.911	65	10	2.09%	34	14	1.09%
Northside	4.41	2612	593	55	8	3.711	0.926	198	5	7.58%	8	28	0.31%
Oakland/Winchell	5.25	2558	487	83	13	4.777	1.081	71	10	2.78%	24	23	0.94%
Oakwood	1.06	1121	1054	55	10	3.691	0.921	28	9	2.50%	12	17	1.07%
South Westnedge	5.49	2541	462	83	14	4.992	1.130	34	17	1.34%	14	36	0.55%
Southside	0.56	305	545	43	11	4.212	1.120	7	11	2.30%	3	21	0.98%
Stuart	0.35	366	1033	31	10	3.454	1.006	15	4	4.10%	1	24	0.27%
Vine	2.10	2129	1012	60	11	4.051	0.989	122	5	5.73%	12	25	0.56%
West Douglas	1.31	444	338	44	11	3.959	1.046	13	5	2.93%	5	17	1.13%
West Main Hill	0.78	733	944	56	11	4.316	1.072	36	4	4.91%	0	—	0.00%
Westnedge Hill	2.66	1809	679	63	9	4.103	0.990	89	5	4.92%	7	28	0.39%
Westwood	1.90	625	328	59	10	4.245	1.041	32	6	5.12%	1	38	0.16%
City of Kalamazoo	**58.45**	**25754**	**441**	**126**	**11**	**4.496**	**0.930**	**967**	**7**	**3.8**	**170**	**22**	**0.7**

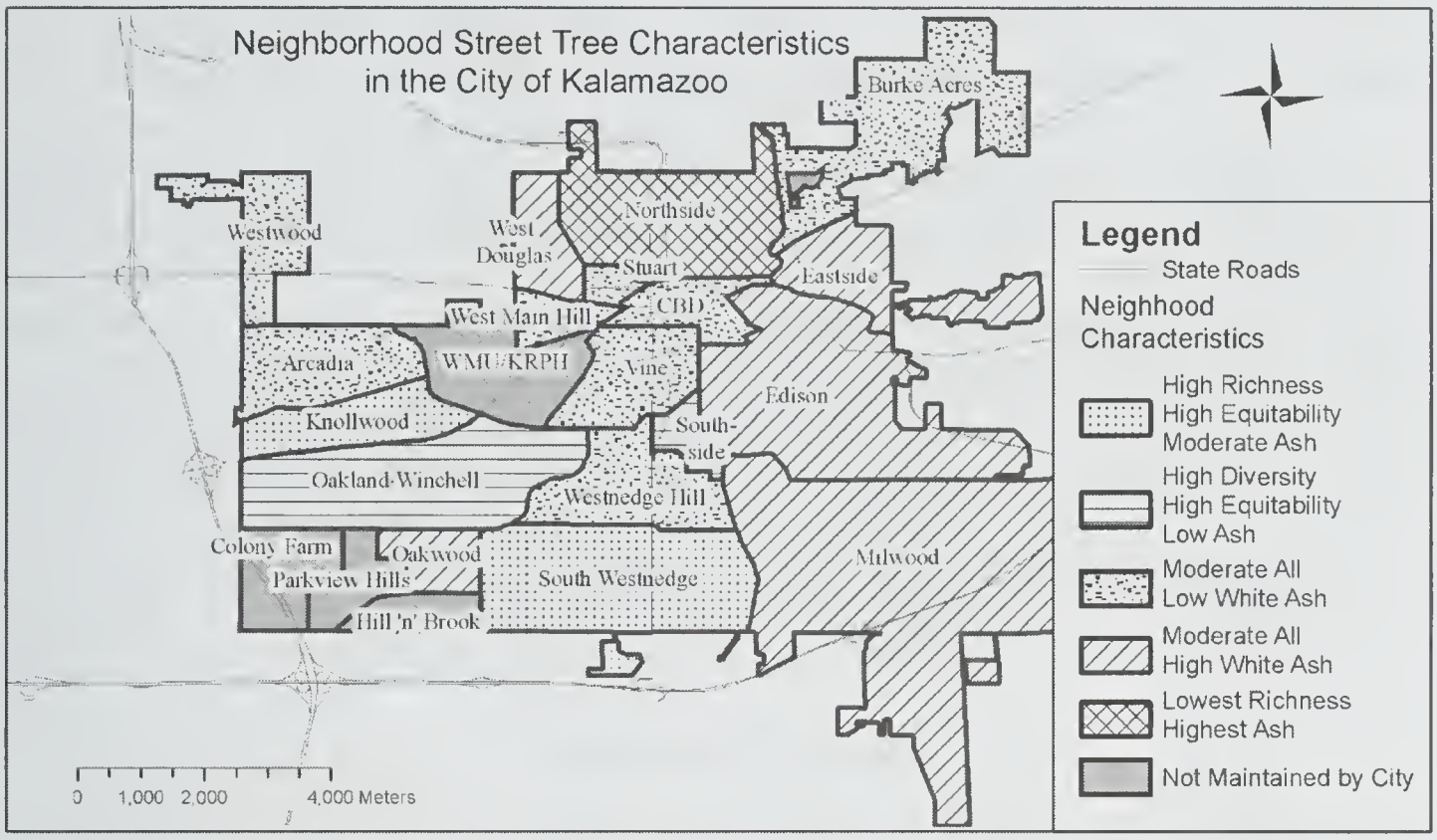

FIGURE 3. Street tree community types in the 18 neighborhoods of Kalamazoo, Michigan. Street tree community characteristics indicated in legend are those variables in the results of hierarchical cluster analysis that distinguish each community type from the others.

but these neighborhoods have the highest values in nearly every variable except frequency of ash. Knollwood and South Westnedge have the highest equitability values, a moderate to high number of species considered dominants and very low percentages of *F. pennsylvanica*. Oakland/Winchell and Southside neighborhoods are similar in terms of dominants, but have a lower equitability than Knollwood and South Westnedge and a lower frequency of ash. South Westnedge and Oakland/Winchell have the highest number of dominant species and highest diversity of any neighborhoods in the city.

DISCUSSION

Both green ash (*F. pennsylvanica*) and white ash (*F. americana*) have been popular street trees in cities throughout the U.S. Removal of these species and decisions regarding replacement planting will have implications with regards to urban biodiversity and regional susceptibility to further epidemics.

Northside neighborhood is unique, with the lowest number of dominant species and lowest species richness in the city. Northside also has the highest percentage of *F. pennsylvanica* in the city. These characteristics make Northside especially vulnerable to the emerald ash borer. Because Northside also has the lowest socio-economic status of Kalamazoo's neighborhoods (U.S. Census Bureau, 2000), assistance should be given to residents for replanting purposes if the overall diversity of the city is to be maintained or increased.

Our analysis of neighborhood street tree characteristics highlights the high variability in diversity, equitability, and role of individual species even within a

modest sized Midwestern city. In general, species richness and ash tree densities are lowest in the urban center where neighborhoods are older. The edges of the city, where new developments are taking place, have a general trend toward increasing species richness. It is our hope that as residents are forced to replant street trees due to the impact of EAB, they choose replacements with an eye to enhancing local biodiversity. With this in mind, we are using the data collected in this study to design and implement a prototype spatial decision support system to assist residents in replacing damaged street trees. For input home locations within the city, the system will examine the number of street trees of each species within 200 meters of the home location and compile a list of potential replacement tree species that are not already dominant in the area. The lists will specify and highlight native tree species and species that provide food and cover for wildlife.

ACKNOWLEDGEMENTS

This research was funded by the Hanes Trust. Data were provided by the Kalamazoo City Forester, Todd Pryor. The authors gratefully acknowledge the research assistance provided by Kenneth Hilker throughout this project. We also thank C. Elizabeth Whately and two anonymous reviewers for helpful comments which clarified several points in the text.

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APPENDIX A. List of documented street trees in Kalamazoo, Michigan.

The list is arranged alphabetically by family, genus, and species.

ALTINGIACEAE	
Liquidambar stryraciflua L.	Sweetgum
ANACARDIACEAE	
Cotinus coggygria L.	Smoketree
Rhus aromatica Aiton	Fragrant sumac
BETULACEAE	
Betula nigra L.	River birch
Betula papyrifera Marsh.	Paper birch
Betula pendula Roth.	European white birch
Betula populifolia Marsh.	Gray birch
Carpinus caroliniana Walter	Blue beech / Ironwood
Ostrya virginiana (Miller) K. Koch	Hop hornbeam
BIGNONIACEAE	
Catalpa speciosa (Warder) Warder ex Engelm.	Northern catalpa
CANNABACEAE	
Celtis occidentalis L.	Hackberry
CERIDIPHYLLACEAE	
Cercidiphyllum japonicum Sieb & Zucc. Ex J. Hoffman & H. Schult.	Katsura tree
CORNACEAE	
Cornus florida L.	Flowering dogwood
CUPRESSACEAE	
Juniperus communis L.	Common juniper
Juniperus virginiana L.	Red cedar
Metasequoia glyptostroboides Hu & W.C. Cheng	Dawn redwood
Thuja occidentalis L.	Northern white cedar
ELAEAGNACEAE	
Elaeagnus angustifolia L.	Russian olive
FABACEAE	
Cercis canadensis L.	Redbud
Cladrastis kentukea (Dum. Cours.) Rudd	Kentucky yellowwood
Gleditsia triacanthos L.	Honey locust
Gymnocladus dioicus (L.) K. Koch	Kentucky coffee tree
Robinia pseudoacacia L.	Black locust
Sophora japonica (L.) Schott	Japanese pagoda tree
FAGACEAE	
Fagus grandifolia Ehrh.	American beech
Fagus sylvatica L.	European beech
Quercus acutissima Carruth.	Sawtooth oak

Quercus alba L.	White oak
Quercus bicolor Willd.	Swamp white oak
Quercus coccinea Münchh.	Scarlet oak
Quercus imbricaria Michx.	Shingle oak
Quercus macrocarpa Michx.	Bur oak
Quercus palustris Münchh.	Pin oak
Quercus prinus L.	Chestnut oak
Quercus rubra L.	Red oak
Quercus velutinaLam.	Black oak
GINKGOACEAE	
Ginkgo biloba L.	Ginkgo
JUGLANDACEAE	
Carya cordiformis (Wangenh.) K. Koch	Bitternut hickory
Carya glabra (Mill.) Sweet	Pignut hickory
Carya ovata (Mill.) K. Koch	Shagbark hickory
Carya tomentosa (Lam.) Nutt.	Mockernut hickory
Juglans cinerea L.	Butternut
Juglans nigra L.	Black walnut
LAURACEAE	
Sassafras albidum (Nutt.) Nees	Sassafras
MAGNOLIACEAE	
Liriodendron tulipifera L.	Tulip tree
Magnolia acuminata (L.) L.	Cucumbertree
Magnolia* × *soulangiana Soul.-Bod.	Saucer magnolia
MALVACEAE	
Tilia americana L.	L. Basswood
Tilia cordata Mill.	Small-leaved linden
Tilia tomentosa Moench	Silver linden
Tilia* × *euchlora K. Koch	Crimean linden
MORACEAE	
Morus alba L.	White mulberry
OLEACEAE	
Fraxinus americana L.	White ash
Fraxinus nigra Marsh.	Black ash
Fraxinus pennsylvanica Marsh.	Green ash
Syringa reticulata (Blume) H. Hara	Japanese tree lilac
Syringa vulgaris L.	Common lilac
PINACEAE	
Abies balsamea (L.) Mill.	Balsam fir
Abies concolor (Gordon & Glend.) Lindl. ex Hildebr.	White fir
Picea abies (L.) H. Karst.	Norway spruce
Picea glauca (Moench) Voss	White spruce
Picea omorika (Pančić) Purk.	Serbian spruce
Picea pungens Engelm.	Blue spruce
Pinus nigra J. F. Arnold	Black pine / Austrian pine
Pinus resinosa Aiton	Red pine
Pinus strobus L.	White pine
Pinus sylvestris L.	Scots pine
Pseudotsuga menziesii (Mirb.) Franco	Douglas fir
Tsuga canadensis (L.) Carrière	Eastern hemlock
PLATANACEAE	
Platanus occidentalis L.	Sycamore
Platanus* × *acerifolia L.	London plane tree
RHAMNACEAE	
Rhamnus cathartica L.	Common buckthorn
ROSACEAE	
Amelanchier arborea (F. Michx.) Fernald	Downy serviceberry

Crataegus crus-galli L.	Hawthorn / Cockspurthorn
Crataegus phaenopyrum (L. f.) Medik.	Washington hawthorn
Malus pumila Mill.	Apple
Prunus avium (L.) L.	Sweet cherry
Prunus cerasifera Ehrh.	Cherry plum
Prunus virginiana L.	Choke cherry
Prunus persica (L.) Batsch	Flowering peach
Prunus serotina Ehrh.	Black cherry
Prunus serrulata Lindl.	Japanese cherry
Pyrus calleryana Decne.	Callery pear
Sorbus americana Marsh.	Mountain ash
RUTACEAE	
Phellodendron amurense Rupr.	Amur corktree
SALICACEAE	
Populus balsamifera L.	Balsam poplar
Populus deltoides W. Bartr. ex Marsh.	Cottonwood
Populus grandidentata Michx.	Bigtooth aspen
Populus tremuloides Michx.	Quaking aspen
Salix babylonica L.	Weeping willow
Salix discolor Muhl.	Pussy willow
Salix matsudana Koidz.	Corkscrew willow
SAPINDACEAE	
Acer campestre L.	Hedge maple
Acer griseum (Franch.) Pax	Paperbark maple
Acer negundo L.	Boxelder
Acer palmatum Thunb.	Japanese maple
Acer platanoides L.	Norway maple
Acer pseudoplatanus L.	Sycamore maple
Acer rubrum L.	Red maple
Acer saccharinum L.	Silver maple
Acer saccharum Marsh.	Sugar maple
Acer tataricum L. subsp. ***ginnala*** (Maxim.) Wesm.	Amur Maple
Aesculus hippocastanum L.	Horse chestnut
Koelreuteria paniculata Laxm.	Goldenrain tree
SCROPHULARIACEAE	
Paulownia tomentosa (Thunb.) Steud.	Princess tree
SIMAROUBACEAE	
Ailanthus altissima (Mill.) Swingle	Tree of heaven
TAXACEAE	
Taxus canadensis Marsh.	Canada yew
THEACEAE	
Stewartia pseudocamellia Maxim.	Japanese stewartia
ULMACEAE	
Ulmus americana L.	American elm
Ulmus glabra Huds.	Scots elm
Ulmus parvifolia Jacq.	Chinese elm
Ulmus pumila L.	Siberian elm

BOOK REVIEWS

Burger, W. C. 2006. Flowers: how they changed the World. Prometheus Books, Amherst, NY, 337 pp. ISBN 1-59102-407-2 $23.00.

Sometimes it is said that "old botanists never die, they just turn into compost." Anyone who is acquainted with the author of this book, the size of a 'Peterson's Guide' book knows Bill is not ready to turn into compost.

Bill Burger traces his interest in the natural world to growing up in a family who spent time escaping the canyons of New York City to a cabin in the Hudson Highlands north of the city. Allowed to sharpen his sense of wonder and challenged by a high school teacher, Bill embarked on a life of studying plants from Ethiopia to Central America to the intriguing woods and dunes of northern Indiana and southwestern Michigan from the Field Museum of Natural History, Chicago. Now, after over 50 years studying the "world of green," Burger takes the reader along for an eye opening journey into the world of flowers and the reasons why the flowering plants have become the dominant group of organisms populating the earth's surface. His easy flowing style of writing through chapters like "What, Exactly, Is a Flower, Flowers and Their Friends" and another ". . . Their Enemies," to "How Flowers Changed the World" could only be written by a person with a wealth of knowledge and a passion for sharing the subject. To add emphasis to the subject, outstanding color images of flowers along with some of their friends are included in the middle of the book.

The amateur gardener-botanist will greatly enjoy the reduced use of big words in explaining complex subjects, and yet for those words used in the book there is an ample glossary at the end.

If you are looking for a book to read while lying on a sunny beach or before a crackling fire as the snow drifts by your window, here is the book for you. A great stocking stuffer! We need more writing like this to keep the botanical interest going in future generations.

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Bagust, H. 2003. The Firefly Dictionary of Plant Names: Common and Botanical. Firefly Books (US) Inc., Buffalo, NY, 440 pp. ISBN 1-55297-602-5 $24.95.

If you travel throughout other English speaking countries, it quickly becomes apparent that we in North America have an aversion toward using Latin names for plant species, whereas other cultures use them freely to communicate. At present, only approximately 12–15% of wild plant species have a common or vernacular name given to them. Well you botanical name haters and avid gardeners

are now in luck. Herald Bagust has compiled a 400+ page book that can fit in your fanny pack that includes over 30,000 common and botanical names of plants grown in English-speaking areas of the world. He states that this book is to be "a working tool for amateur and professional gardeners as well as for plant lovers wishing to find the botanical name when only the common name is known."

The volume is divided into 14 different plant sections under two main heading of Common Names and Botanical Names. The names are then arranged alphabetically beginning with alpines and rockery plants and concluding with trees, bushes and shrubs and wild flowers. These listed names should help satisfy the general gardeners wanting common names. However, the botanist or person wanting to add more non-commercial native species to their garden or landscape will still have to learn the Latin name. But, is that really difficult? After all, have you tried to pronounce or remember some of the human names of your co-workers? That's right, we learn them!

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Pettigrew, J. and B. Richardson. 2005. *The Tealover's Companion. A Guide to Teas throughout the World.* The National Trust Enterprises Ltd., London, UK, 176 pp. ISBN 0-7078-0390-X 14.99 Pounds.

Four years ago I reviewed, in *The Michigan Botanist*, a book on tea and its infusions. If you are a tea drinker this present book goes further in various topics than the previous book. Let me tell you about it.

The two authors, who own fine tea rooms and restaurants, are recognized experts in the knowledge of tea in the United Kingdom and United States, take 24 pages (p. 6–30) to trace the history of tea from its discovery to establishment of upscale tea houses to the recent renaissance of tea drinking throughout the World. Next they talk about the biology of the species of tea, especially *Camellia sinensis* the main species of the evergreen plants. There are two other subspecific taxa: *assamica* and *lasiocalyx* rounding out the group grown commercially. Here is discussed, with the use of color photographs, the horticulture of growing and harvesting tea, the types and manufacture of tea and the ways to decaffeinate tea. Discussion also includes the grading, blending, selling, storing and the various ways tea can be packaged. Traditional as well as modern ways of getting the best flavor from tea are explained. You will learn that the old "rule of thumb" of just steeping a bag of tea for 3–5 minutes does not apply for a good cup of tea.

The remaining 2/3 of the book is The Directory, a pectoral guide to 80 world teas beginning with China and ending with Zimbabwe. In this color coded part of the book you will find fine images of the name of a tea (e.g. Bancha, Formosa Gunpowder, Gyokuro, Lover's Leap, Lu Mudan, Matcha, Poobong, Sencha, etc. to name a few), character and brewing tips (e.g. brewing times from 15 sec. to 7

minutes and steeping many times over). The color of the liquid can be mouth watering and at times seems to flow off the page. The book concludes with some useful names, location addresses, phone numbers and e-mail addresses for tea-rooms and tea suppliers in the United Kingdom, the United States and the rest of the world. Some I recognized as having visited, while others were noted for future reference.

If you are a tea drinker and wish to get the most out of what you are enjoying each day, I highly recommend this little book. You will not be disappointed and will find your relaxing sip of tea will become that much more enjoyable after reading it.

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Hágsater, E., M. Á. Soto Arenas, G. A. Salazar Chávez, R. Jiménez Machorro, M. A. Lopez Rosas, and R. L. Dressler. 2005. ORCHIDS OF MEXICO, Instituto Chinoín, Mexico City. Hard cover, 304 pp. ISBN 968-7889-08-X. US$100 plus shipping; available from Redacta, S.A. de C.V., Av. Primero de Mayo 249, San Pedro de los Pinos, 03800 Mexico, D. F., Mexico. A version in Spanish is out of print.

This beautiful "coffee-table" book is a magnificent account of some 450 selected orchid species found in Mexico, organized by the plant communities in which they occur. Before beginning a somewhat formal account of the species, the book provides a description of the Mexican landscape, a summary of the climate, a spectacular two-page image spread of Mexico from space (a mosaic of cloudless images on a digital terrain model). Following this is a map of the floristic provinces of Mexico, then an ecological description of the various major units of vegetation, beginning with tropical rain forests and going on to tropical dry forests, wetlands and coastal vegetation, arid zones and scrubs, grasslands, paramos, and alpine vegetation, temperate forests, and cloud forests. The distribution of each major vegetation type is shown on attractive relief maps.

The first major element of the book is a chapter on natural history, concerning growth habits, roots, mycorrhiza, stems, leaves, flowers, pollination, seeds and germination, and classification. This is followed by a chapter on orchids and people, then a consideration of the Mexican landscape (in which the image of Mexico from space is provided). Following these introductory aspects the formal account of the species organized by community types is provided. The taxonomic purist might be somewhat frustrated by this organization, in that there is no systematic enumeration of the species, rather miscellaneous discussions of various species. For this reason the book would have to be considered one on the ecology of Mexican orchids rather than a systematic account, and for this reason the title of the book is misleading.

In the chapter on orchids and people is a fascinating account of *Stanhopea hernandezii* and other species documenting the 16th century interest in orchids

by the native peoples, long before they gained popularity in Europe. We do not normally think of orchids as a source of glue, but such is the case for the mucilage from corms or pseudobulbs of various species of *Laelia, Prosthechea,* and *Bletia*. A detailed account is provided for the economically most important orchid, *Vanilla planifolia*, including its dated spread throughout the tropical world, from the Philippines ca. 1700 to England (1800), Java (1819), Mauritius and Réunion (1827), Madagascar (1840), Tahiti (1848), Seychelles (1866), and Uganda (1912).

This chapter also provides a rather detailed account of research on and collecting of Mexican orchids. Noteworthy among these authors and collectors, beginning with Francisco Hernández in the 16th century, going on to the work of Sessé and Mociño (1787–1803). In the 19th century prominent European names include Humboldt and Bonpland, Lexarza and de la Llave, Bateman, Lindley, Schiede, Hartweg, Ghiesbreght, Ehrenberg, Liebmann, and Galeotti. Among American collectors the names Parry, Palmer, Thurber, Rose and Pringle are prominent. The important 20th century taxonomic account is that of L. O. Williams (1951) on *The Orchidaceae of Mexico*.

The photographs of the landscapes, habitats and plants are beautiful. The book was printed in Japan on acid-free paper. It was sponsored by the pharmaceutical company Chinoín, a company devoted to production of pharmaceuticals for human and animal health care. As stated in their introduction, the information provided in each chapter covers many aspects of the natural history of Mexican orchids. They consider how these species occur in the major plant communities and their importance to human populations. It is noted that the book is complemented by an updated checklist of the orchids of Mexico and a catalogue in digital format of the photographed species, but the sources of this information are not provided. However, this is readily found with a Google search, which yields the URL www.orchidsbooks.com/book.asp.id=1178. The catalogue references some 1,500 pictures, including about 90 percent of the Mexican orchids. The checklist is included in the catalogue.

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Walewski, J. 2007. *Lichens of the North Woods*. Kollath+Stensaas Publishing, 394 Lake Avenue South, Suite 406, Duluth, MN. 160 pp. ISBN-13: 978-09792006-0-1, paperback, $18.95.

Lichens, the symbiotic association between fungi, green algae and/or cyanobacteria, are all around us, but frequently go unnoticed. So begins Joe Walewski's "Lichens of the North Woods", published as part of the "North Woods Naturalist Series" by Kollath+Stensaas Publishing. This richly illustrated field guide, which is aimed at non-specialists, provides an excellent introduction

to lichens. The book begins with a concise, yet thorough summary on lichen biology, their importance to ecosystem function, and the many connections between lichens and a number of organisms. Drawings and photos are included throughout the introductory sections, supplementing the discussion on lichen anatomy and ecology. Especially interesting, is an excellent figure documenting the slow growth of one of the most frequently encountered lichens in the North Woods (*Flavoparmelia caperata*, the common greenshield lichen).

Following the introductory sections, the book shifts to lichen identification, and is divided into 3 sections, corresponding to substrate (ground, rocks and trees). These sections occupy the majority of the book, and provide color images and descriptions of 111 species, focusing on common or interesting species. Species found on each substrate are further divided by growth form (crustose, foliose or fruticose) making this guide especially easy to use. Each substrate section begins with a discussion on the importance of the substrate to lichens and what lichens might be encountered on this substrate. This is followed by a listing of the common and latin names of the species (again, ordered by growth form) illustrated in that section. A full page is then devoted to each species, including a color photograph, a morphological description of the taxon, its chemistry (oftentimes important for lichen identification), how to discern it from look-alike species, and a "nature note", which provides interesting additional details about this particular lichen or lichens in general. Often 2 pictures are included for each species, showing a larger image of the lichen as well as a close-up of a key feature used for identification, or also showing wet and dry photos of the same species.

Future editions of this book might focus less on *Cladonia* and *Peltigera* species (of which many are featured) and include taxa from other genera, such as *Chaenotheca* (stubble lichens), which is used as an indicator of forest continuity, and *Diploschistes muscorum* (cowpie lichen), a crustose lichen which obtains its photobiont by parasitizing *Cladonia* species, and later switches to yet another photobiont. It might also be of interest to briefly discuss the other organisms that live on or in lichen thalli, such as lichenicolous fungi (which can parasitize lichen symbionts) and non-photosynthetic bacteria. This would further illustrate the diversity of life contained within a lichen thallus. However, the book is in no way impaired by these omissions.

I highly recommend this book to anyone with an interest in lichens or biodiversity. One does not need to be a lichen specialist to enjoy, appreciate or use this book as the author is careful to avoid technical jargon and has distilled a wealth of information into this field guide, which can easily fit into a pocket ($8 \times 4.4 \times 0.5$ inches). The book is easy to use, and contains many of the commonly encountered species in the area. Walewski's enthusiasm and passion for lichens is evident throughout the book, making this an especially enjoyable read and valuable contribution.

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8. Italicize all scientific names. Voucher specimens must be cited for floristic works or any other relevant study. Papers citing plant records without documenting vouchers are generally not acceptable.

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On the cover: *Bluebill Creek, Ottawa National Forest, Gogebic Co., MI. This slow-moving, meandering stream is typical of the region, possessing many chemical qualities and flora of a palustrine wetland. Photograph taken by Karen Francl in 2004. See page 81 for related text.*

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FLORA OF AMNICON FALLS STATE PARK, DOUGLAS COUNTY, WISCONSIN

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ABSTRACT

The vascular plants and plant communities observed from 2006 to 2008 at Amnicon Falls State Park, located in Douglas County, 24 kilometers east of the city of Superior and eight kilometers south of Lake Superior in northwestern Wisconsin are presented. The most commonly encountered plant communities were the spruce/fir boreal forest and the aspen/birch forest. The vascular plant list included 400 taxa from 79 families. There were 19 ferns and fern allies, seven gymnosperms, and 374 angiosperms. Fifteen county records were discovered in the course of the survey, as well as the observation and confirmation of one species listed as threatened and seven species listed as special concern in the State. These data are presented to document floral composition, and to provide a base for future research activities within the park and region.

KEYWORDS: Amnicon Falls State Park, Douglas County flora of Wisconsin, boreal forest, northern Wisconsin plant communities

INTRODUCTION

The area of study was Amnicon Falls State Park (AFSP) of the Wisconsin Department of Natural Resources' State Park System. The park is approximately 338 hectares in size, and located in Douglas County, 24 kilometers east of the city of Superior and approximately eight kilometers from the shores of Lake Superior in northwestern Wisconsin. The main feature of the Park is the series of waterfalls where the Amnicon River crosses the Superior escarpment (Figure 1).

The Park is primarily forested and dominated by boreal forest, northern pine forests, and an aging forest of aspen and birch. The other less dominant communities included: alder thickets, sedge meadows, cliffs, small streams, the fluvial zone, and black ash swamps. Of particular interest was the boreal forest. This plant community was very restricted in Wisconsin prior to European settlement, covering approximately 1.9% of the land area (Curtis 1959). Curtis noted that one of the best developments of this forest type was found along the shore of Lake Superior, which included the area of AFSP.

Examination of the early land survey records confirms the findings of Curtis. Stuntz's (1852–1854) general description of the township noted, "the timber in the township is small spruce, tamarac, birch, fir, and cedar" (assumed to be *Picea glauca, Larix laricina, Betula papyrifera, Abies balsamea,* and *Thuja*

FIGURE 1. The upper falls of the Amnicon River. The river flows over exposed basalt bedrock on its way to Lake Superior, approximately eight kilometers to the north. (Photo by Derek Anderson.)

occidentalis, respectively). A closer inspection of the section line notes of the areas immediately surrounding AFSP, revealed a number of species associated with the boreal forest, and confirms the small timber reference of the township general description. Some of the trees observed included white birch (*Betula papyrifera*), with diameters 15cm–30cm; tamarack (*Larix laricina*), with diameters 22cm–25cm; spruce (*Picea glauca*), with diameters 18cm–30cm; white pine (*Pinus strobus*), with diameters: 20cm–71cm; and aspen (*Populus spp.*), with diameters 20cm–36cm. The topography was noted as gently rolling with undergrowth typically of hazel (*Corylus spp.*), alder (*Alnus spp.*), fir (*Abies balsamea*) and maple (*Acer spp.*) (Stuntz 1852–1854).

The climate of the region is continental; however, influences from Lake Superior provide an oceanic-like microclimate to those areas adjacent to the lake. Lake Superior, with an average annual temperature of 4°C, moderates the climate, making winters warmer and summers cooler (Minnesota Sea Grant 2008). Based on weather data from Superior, the mean annual precipitation is 78.2 cm with July having the greatest precipitation (10.8 cm). Mean annual temperature is 4.9° C with the hottest month being July (average 19.2° C) and the coldest being January (average –11.1° C). The growing season (frost free) ranges from 109 to 189 days with an average of 143 days per year (Midwestern Regional Climate Center 2007).

Development within the Park is fairly limited, and consists of a contact station, campground, picnic area and 2.9 kilometers of trails (WIDNR 2006a).

One of the larger disturbed areas, and home to several large populations of invasive plants, is the approximately 100 meter-wide cut that bisects the park to accommodate the Lakehead pipeline. This pipeline traverses east to west 1.6 kilometers through the Park. The north half is dominated by the aspen and birch forest and the southern half is dominated by boreal and pine forests. Two-thirds of the Park's acreage continues to recover from farming and logging disturbances from early in the twentieth century (W. Eldred, personal communication).

Geology

Approximately one billion years of geologic activity are evident at AFSP. The activity included: volcanic eruptions, the advance of great oceans, the formation of sandstone, earthquakes and glaciation (Green et al. 1977). One billion years ago, a mid continent rift started to form on the North American continent. Lava spread across the region, and as it cooled basalt formed. This rock was observed in the upper falls of the park. Five-hundred million years ago, an ancient ocean covered the basalt (Minnesota Sea Grant 2008). Streams carried sand to this ocean, and over time these sands were compressed into sandstone as they accumulated on top of the basalt (the horizontal layers of this sandstone remain visible along the riverbank near the lower falls of the park) (Figure 2). Over time, the basalt underwent tremendous fracturing and movement. The conclusion was the formation of the Douglas Fault, which extends from just east of Ashland, Wisconsin to the Twin Cities region of Minnesota. If the up thrusting had not occurred, the basalt that is visible today would be several thousand feet below the sandstone. Evidence of the fault can be observed at the present day location of the Upper Falls, Snake Pit Falls, and the Now and Then Falls of AFSP (Dott and Attig 2004).

Finally, the area underwent a series of glaciations, with the last event ending about 10,000 years ago. The glacial melt water scoured the basalt bedrock and caused the sloughing of the sandstone cliffs in the park. Glacial deposits of lacustrine red clays that formed the old lake plain of Glacial Lake Duluth were left behind (LaBerge 1994). These soils were finely textured, resulting in very poor drainage. The surface clay deposits effectively prevented ground water from reaching the surface as springs, and consequently created artesian well conditions (Douglas County Land Conservation Committee 2005).

Land History

The cultural history of the park is a critical component in understanding the plant communities observed today. The Amnicon Falls area had a rich cultural history and a diversity of uses by native peoples and European settlers. Native peoples traveled to this area as early as 9,000 years ago—a thousand years after the last ice sheets melted from the shores of Glacial Lake Duluth (WIDNR 2006a). While Native Americans (Ojibwa) were in the area, there is evidence that they sought out some of the copper resources located in the park. The first Europeans were also drawn to the area in the 1850s for the same cop-

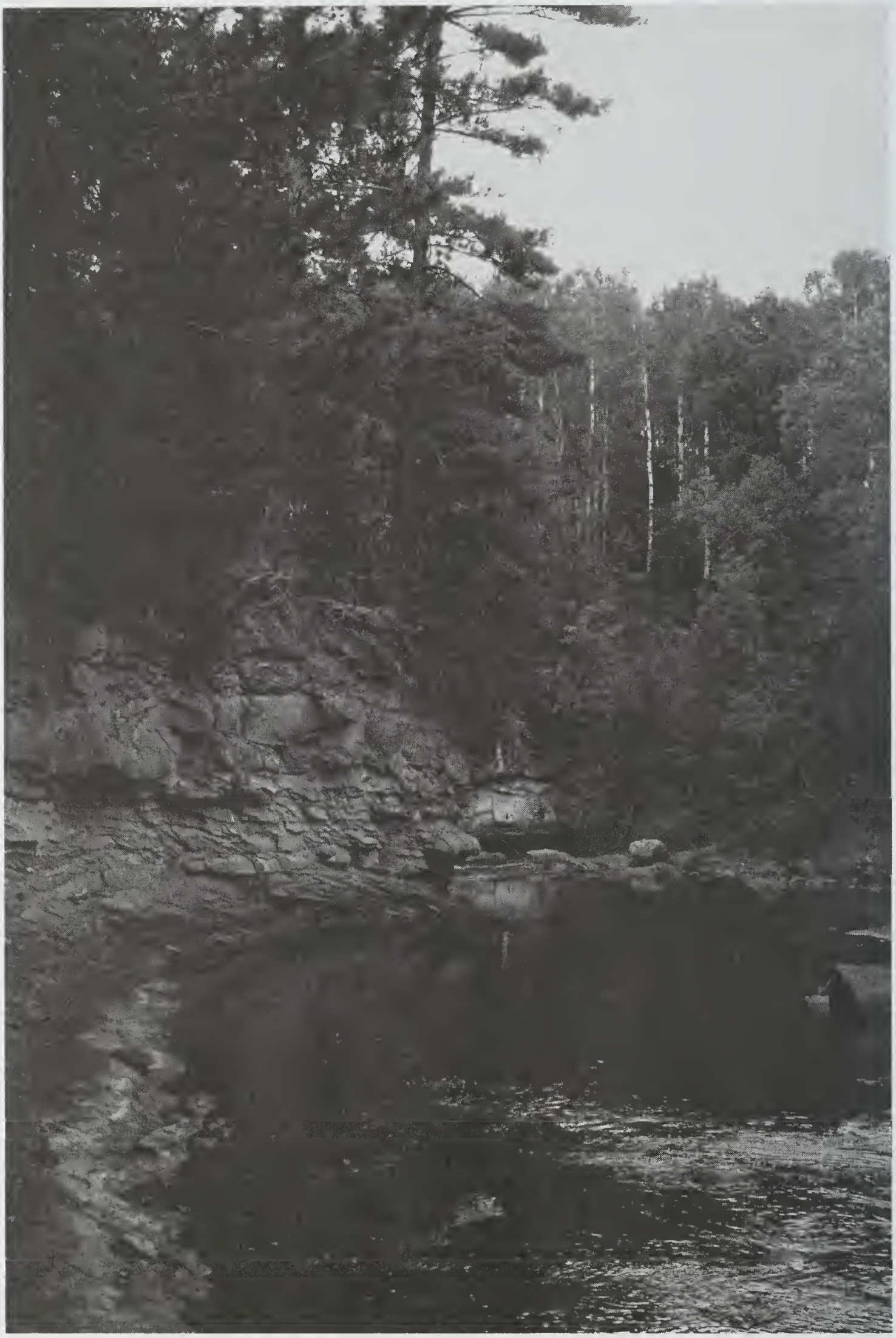

FIGURE 2. Sandstone is exposed in a bend of the Amnicon River, on the north side of the park. The cracks in the exposed rock provide habitat for a number of species. (Photo by Derek Anderson.)

per resources. Though some people had moderate success, the majority failed. Evidence of their pits is still observed today along the nature trail in the park. A second effort of mining occurred on the downside of the Superior escarpment, in the sandstone areas of the park. Brownstone quarries were opened up and a staging area was created around 1850 and used through the 1870s. Today, this area remains an open field.

In 1866, James Bardon purchased 64.75 hectares from the Chicago, St. Paul, Minneapolis and Omaha Railroad Company. Logging activities commenced soon after and the Amnicon River was used as a sluiceway to transport the logs to the lake, which were later floated to Duluth and Superior to build these new cities. The area was logged over by the 1920's and portions were farmland as late as the 1950's (W. Eldred, personal communication). In 1932, Douglas County purchased 24.28 hectares and the Bardon family donated 26.30 hectares and the place became known as Bardon Park. Between 1932 and 1961, the park was alternately managed by the Town of Amnicon and Douglas County. Finally, in 1961, the park was transferred to the state and named Amnicon Falls State Park. In 1967, the campground was developed in an area mixed with boreal and pine forest elements.

The current project was undertaken to provide baseline data on the flora of this park and region, as these data are lacking in northwestern Wisconsin in general.

METHODS

The park was visited throughout the growing seasons of 2006, 2007 and 2008. Over 1100 voucher specimens were collected, identified, and deposited in the John W. Thomson Herbarium of the University of Wisconsin – Superior, Superior, Wisconsin (SUWS). For general plant identification, the Spring Flora of Wisconsin (Fassett 1978), the Grasses of Wisconsin (Fassett 1951), the Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Gleason and Cronquist 1998), the Illustrated Companion to Gleason and Cronquist's Manual (Holmgren 1998), the Aquatic and Wetland Plants of Northeastern North America (Crow and Hellquist 2000), the Trees and Shrubs of the Upper Midwest (Rosendahl 1955), and the Michigan Flora (Voss 1972, 1985, 1996) were extensively used. Nomenclature follows the published volumes of the Flora of North America (1993+) and then Wetter et al. (2001).

Eighteen randomly placed plots were marked in the dominant forest plant communities to capture the basic composition of each major plant community within the park. Dimensions of each plot were 20 meters by 50 meters in size and contained nested plots, arranged in the style of the Whittaker Plant Diversity Sampling Method (Shmida 1984; Barbour et al. 1987). Meander searches were used to search smaller, more unique plant communities and microhabitats such as the cliff faces, rock outcrops, fluvial habitats and the black ash swamps (Goff and Glenn 1982).

A database query of Wisconsin herbaria was used to identify additional plants that have been collected from AFSP (Robert W. Freckmann Herbarium 2008; Wisconsin State Herbarium 2008). The majority of species were collected in the heavily visited area of the park, while only a few were collected from the north end of the park.

RESULTS

A total of 400 vascular plant taxa representing 223 genera and 79 families were documented from the 338-ha park (Appendix I) between 2006 and 2008.

TABLE 1. Rare Vascular Plants Observed

Documented rare plant species (WIDNR 2006b). The year last collected does not take into account incidental observations that may have occurred.

Species	No. of Occurrences	Year Last Collected	Status
Clematis occidentalis	2	1974	Special Concern
Cypripedium parviflorum var. *makasin*	1	1975	Special Concern
Cystopteris laurentiana	6	1975	Special Concern
Dryopteris fragrans	1	1975	Special Concern
Geum macrophyllum	2	New Record	Special Concern
Juncus vaseyi	1	1995	Special Concern
Petasites frigidus var. *sagittatus*	1	New Record	Threatened
Scirpus georgianus	1	New Record	Special Concern

The fern and fern allies were represented by 19 taxa. Gymnosperms were represented by seven taxa. Of the remaining angiosperms, 100 were monocots, and 274 were dicots. The predominant plant families observed were Asteraceae with 49 taxa, Cyperaceae with 35 taxa, Poaceae with 29 taxa, and Rosaceae with 28 taxa. One rare species listed as Threatened and seven species listed as Special Concern by the Wisconsin Department of Natural Resources, Bureau of Endangered Resources (WIDNR 2006b) were also observed (Table 1). There were a total of 51 introduced species documented, some of which are ecologically invasive.

The introduced species represented approximately 13% of the flora. Introduced plants were concentrated in those areas along the pipeline, the riverbed and banks (especially north of the pipeline crossing), and the northern third of the park that was once farmed, which contained a small amount of common buckthorn (*Rhamnus cathartica*). The sedge meadow area supported a diversity of plants despite the general dominance of reed canary grass (*Phalaris arundinacea*) throughout a large portion of the area and a small 25 square meter area of purple loosestrife (*Lythrum salicaria*). Several non-native species, many of the Fabaceae family, were found adjacent to County Highway U, which represents the eastern boundary of the park. Currently, many of these species are confined to the roadside right-of-way. The interior portions of the park had the best representation of native flora, and typically were devoid of human activity.

The survey of AFSP also resulted in the discovery of 15 species yet to be reported from Douglas County. *Scirpus georgianus*, one of the new county records, had only been cited a few times in the state of Wisconsin (R. Freckmann, personal communication). See Table 2 for the complete list of species newly reported in Douglas County. Another result of the survey was the discovery of 15 taxa that had not been collected in Douglas County in more than 30 years. Of particular interest was *Carex merritt-fernaldii* as this species had not been collected in the county since 1897. There were also several taxa that had not been collected since the 1940s, and these include: *Artemisia serrata, Bidens vulgata, Corydalis aurea,* and *Hypericum pyramidatum.* See Table 3

TABLE 2. New Douglas County Records

Species	No. of Known Occurrences
Carex ormostachya	1
Carex radiata	1
Convallaria majalis	1
Geum macrophyllum	2
Helianthus hirsutus	1
Hydrocotyle americana	3
Pedicularis lanceolata	1
Polygonatum biflorum	Numerous
Quercus × *bebbiana*	1
Ranunculus sceleratus	Numerous
Ribes lacustre	10
Sanicula canadensis	Numerous
Scirpus georgianus	1
Smilax ecirrhata	Numerous
Symphyotrichum lanceolatum var. *interior*	1

TABLE 3. Plants not collected from Douglas County in more than 30 years, until this survey.

Species	No. of Occurrences	Year Last Collected
Artemisia serrata	1	1940
Bidens vulgata	1	1943
Carex bebbii	1	1973
Carex castanea	1	1979
Carex debilis var. *rudgei*	1	1969
Carex merritt-fernaldii	1	1897
Comarum palustre	1	1979
Corydalis aurea	1	1942
Festuca trachyphylla	1	1979
Hypericum pyramidatum	1	1943
Maianthemum trifolium	1	1976
Oenothera villosa	1	1966
Parthenocissus quinquefolia	1	1973
Salix × *rubens*	1	1960
Woodsia ilvensis	Numerous	1975

for the complete list of species not collected in more than 30 years, until this study.

The database survey resulted in a number of specimens that were collected from AFSP in the past. Prominent collectors included Rudy G. Koch and John W. Thomson Jr. The majority of the specimens collected by these individuals are housed at the University of Wisconsin–Superior [SUWS], the University of Wisconsin–Madison [WIS], the University of Wisconsin–La Crosse [UWLC], and/or the Milwaukee Public Museum [MIL] herbaria. There were a total of ten taxa that had previously been collected at the park that were not found during the 2006–2008 survey (Table 4). Some of these species may have disappeared from the park, but a more likely explanation is that these were missed during the survey.

TABLE 4. Taxa and associated information from plants collected at Amnicon Falls State Park, but not observed during the 2006–2008 survey. Herbarium codes: Milwuakee Public Museum [MIL]; University of Wisconsin–Superior [SUWS]; University of Wisconsin–Stevens Point [UWSP]; University of Wisconsin–Madison [WIS].

Species	Collector	Collection No.	Herbarium	Year
Agrostis perennans var. *perennans*	Koch, R. G.	6364	SUWS	1969
Antennaria plantaginifolia	Koch, R. G.	6663	SUWS	1970
Astragalus canadensis var. *canadensis*	Thomson, J. W., Jr.	s.n.	SUWS, WIS	1942
Botrychium virginianum	Somerville, M. F.	80, 81	WIS	1924
Cystopteris bulbifera	Somerville, M. F.	104	MIL	1923
Mitella nuda	Koch, R. G.	5693	UWSP	1969
Selaginella rupestris	Conklin, G. H.	338	WIS	1932
Spiranthes lacera var. *lacera*	Thomson, J. W., Jr.	s.n.	WIS	1942
Stellaria longifolia	Koch, R. G.	7450	WIS	1972
Taxus canadensis	Thomson, J. W., Jr.	s.n.	SUWS, WIS	1942

Plant Communities

The two most common plant communities encountered within the park were a young, even-aged aspen/birch forest and white spruce/balsam fir mixed-aged boreal forest.

Aspen/Birch Forest

The aspen/birch forest was dominated by quaking aspen (*Populus tremuloides*) with typical diameters at breast height (dbh) of 25 to 30 cm (Figure 3). White birch (*Betula papyrifera*) was seldom observed. The typical dbh of the white birch that were measured were 30 to 40 cm. There was very little regeneration of the white birch. However, down and decaying birch was commonplace on the forest floor. In the subcanopy, balsam fir (*Abies balsamea*) was the only tree that rose higher than six meters in height. It was sporadically distributed. The shrub layer contained young white spruce (*Picea glauca*). This species was more common, but less than three meters tall. There were numerous deciduous shrubs present, and the most common species were: arrowwood (*Viburnum rafinesquianum*), nannyberry (*Viburnum lentago*), serviceberries (*Amelanchier spp.*) and hawthorn (*Crataegus sp.*). The ground flora was quite diverse and represented by the following species: *Anemone quinquefolia, Aralia nudicaulis, Athyrium filix-femina, Cornus canadensis, Eurybia macrophylla, Geum aleppicum, Lathyrus ochroleucus, Luzula acuminata, Maianthemum canadense, Maianthemum racemosum, Oryzopsis asperifolia, Rubus pubescens, Uvularia grandiflora,* and *Vicia americana.*

Spruce/Fir Boreal Forest

The mixed aged boreal forest was dominated by balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*). There were a few large (66–81 cm dbh) white pine (*Pinus strobus*) scattered throughout the forest as well. Quaking aspen and white birch were still present, but were part of the subcanopy layer. White cedar (*Thuja occidentalis*) was found along the cool moist valley

FIGURE 3. The canopy of the aspen/birch forest was dominated by quaking aspen (*Populus tremuloides*), while white birch (*Betula papyrifera*) was a minor component. Balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) were seen sporadically through the trees. They were the major components of the subcanopy and shrub layers. (Photo by Derek Anderson.)

floors rising up to the ridge tops. There was little to no evidence of any cedar regeneration. In the shrub layer, the species were similar to those of the aspen/birch forest, with thimbleberry (*Rubus parviflorus*) and round-leaved dogwood (*Cornus rugosa*) playing a more significant role. The ground layer vegetation (Figure 4) changed as the canopy became more coniferous and supported uncommon, but not rare, plants including: *Aralia racemosa, Clintonia borealis, Linnaea borealis, Lonicera canadensis, Pyrola elliptica, Sanguinaria canadensis*, *Shepherdia canadensis,* and *Trientalis borealis.*

Northern Pine Forest (Xeric)

There were only two areas in the park considered northern pine forest (xeric). One was an obvious red pine plantation and the other was a mixture of secondary succession pines (*Pinus resinosa* and *P. strobus)* that began regenerating near the turn of the 20th century (W. Eldred, personal communication). This latter area represented the heart of Amnicon Falls State Park (Figure 5). It was found on a dome of bedrock that was an island within the river. The falls were also the most dramatic in this area. Though the island was small (less than 2 ha), it had numerous trails from heavy visitation. The dominant canopy trees on the island were an equal mix of red pine and white pine, while red pine dominates the less traveled plantation. The subcanopy, shrub, and ground cover layers were poorly represented in these two pine forests. Species found

FIGURE 4. Twinflower (*Linnaea borealis*) was commonly observed in the ground vegetation layer of the spruce/fir forests of the park. Other commonly encountered species in this layer were blue-bead lily (*Clintonia borealis*), starflower (*Trientalis borealis*), and shinleafs (*Pyrola spp.*). (Photo by Derek Anderson.)

FIGURE 5. The pine forest located in the 'heart' of the park was dominated by a mix of even-aged red and white pines (*Pinus resinosa* and *P. strobus*). This area of the park received the bulk of visitor use. The underlying bedrock was close to the surface as seen at the bottom of the photograph. (Photo by Derek Anderson.)

FIGURE 6. Celery leaf buttercup (*Ranunculus sceleratus*) was a Douglas County record found at Amnicon Falls State Park. It was commonly observed in the pools and streams that were found in the sedge-meadow area. (Photo by Derek Anderson.)

in this community included: *Anaphalis margaritacea, Anemone quinquefolia, Corylus cornuta, Diervilla lonicera, Eurybia macrophylla,* and *Pteridium aquilinum.*

Sedge Meadow

A 30-ha sedge meadow occurred at the base of two small ravines, where small streams drain the meadow through a series of small ponds eventually to the Amnicon River. This area appeared to have been flooded by beavers in the past, as several standing snags were observed in the sedge meadow as well. This area was primarily herbaceous, with floating aquatic, submerged, and emergent vegetation (Figure 6). The area was dominated by *Phalaris arundinacea* and *Calamagrostis canadensis,* with *Alisma, Carex, Persicaria, Ranunculus*, *Schoenoplectus* and *Scirpus* well represented. Some of the more interesting plants found in this area were*: Ranunculus sceleratus, Asclepias incarnata, Eutrochium maculatum, Schoenoplectus pungens* and *Scirpus georgianus.*

Black Ash Swamps

There are three black ash swamps primarily in the northern half of the park. The canopy is dominated by *Fraxinus nigra*, though *Fraxinus pennsylvanica* is also present. The soils are often saturated and pools of water collect during periods of high moisture. Plants that grow in this area must be able to tolerate

FIGURE 7. Swamp saxifrage (*Saxifraga pensylvanica*), photographed in early spring, was a commonly observed plant in the black ash swamp. It also appeared in a few additional low areas throughout the park. (Photo by Derek Anderson.)

some periods of total inundation. Many of the trees had formed small buttresses, similar to some southern swamp species. There were no conifers present in the swamp, while seedlings of *Ulmus americana* were found in two of the three swamps. One additional tree of interest found on a narrow upland within one of the swamps was an 18 meter tall hybrid oak, *Quercus x bebbiana*. This cross of *Quercus macrocarpa* and *Q. alba* was an interesting observation. While *Q. macrocarpa* has been observed in several areas of Douglas County, *Q. alba* has rarely been documented. The subcanopy and shrub layer was sporadic with clumps of *Alnus incana* and *Salix spp*. The area was predominately herbaceous in nature and consisted of many graminoid species dominated by *Carex* (12 species recorded). Other common and rare plants in this zone were *Campanula aparinoides, Hydrocotyle americana,* the three forms of *Ranunculus hispidus*, *Ranunculus recurvatus*, *Saxifraga pensylvanica* (Figure 7), and two orchid species – *Cypripedium parviflorum* var. *makasin* and *Platanthera psycodes*, the former being a species of Special Concern.

Fluvial Zone

For the purposes of discussion, the riverbed, its banks, and the river's few islands were included in this zone. This area also contained most of the cliff ferns, which will be discussed in the next section. Of all of the habitats in the park (outside of the sedge meadow) this area received the greatest fluctuation in water levels and flow, as well as the largest amount of direct sunlight. Emergent vegetation and annuals were growing directly in the riverbed. These in-

FIGURE 8. A number of small ravines were observed within the park. These small ravines with exposed bedrock provide habitat for a number of fern species. Common ferns such as polypody fern (*Polypodium virginianum*), rusty cliff fern (*Woodsia ilvensis*), and brittle bladder fern (*Cystopteris fragilis*) were observed here. Laurentian bladder fern (*Cystopteris laurentiana*) and fragrant fern (*Dryopteris fragrans*), both listed as Special Concern, were observed in this setting as well. (Photo by Derek Anderson.)

cluded: *Alisma trivale, Antennaria neglecta, Barbarea vulgaris, Calla palustris, Caltha palustris, Cirsium arvense, Eleocharis ovata, Gnaphalium uliginosum, Hypericum perforatum, Mimulus ringens, Mollugo verticillata, Oenothera biennis,* and *Tanacetum vulgare.* Species present on the riverbanks were: *Angelica atropurpurea, Cicuta maculata, Helianthus giganteus, Heracleum lanatum, Sonchus arvensis, Stachys palustris, Symphyotrichum lanceolatum,* and *Symphyotrichum lateriflorum.*

Cliffs

The cliff habitats were primarily located at the north end of the park at the Upper and Lower falls area, as well as the Now and Then Falls. Several smaller side ravines also provided additional areas of this community type (Figure 8). It was in these areas that *Cystopteris laurentiana* and *Dryopteris fragrans*, two species of Special Concern, were re-discovered for the first time since 1975. Other fern species found in these cliff environments were: *Athyrium filix-femina, Cystopteris fragilis, Dryopteris carthusiana, Gymnocarpium dryopteris, Polypodium virginianum,* and *Woodsia ilvensis.*

Alder Thicket

The last major plant community surveyed was an alder thicket. This community was predominantly found in the southwest corner of the park as well as

in pockets throughout the even-aged aspen/birch forest at the south end. Both of these areas were surveyed and species common to wetlands were observed. These included: *Alnus incana, Calamagrostis canadensis, Carex lacustris, Caltha palustris,* and *Impatiens capensis.*

DISCUSSION

The flora of Amnicon Falls State Park represents a secondary succession of undisturbed forest in northwestern Wisconsin that has now persisted for more than 70 years. There is a mosaic of ridge tops, bottom lowlands, sedge meadows and cliff habitats found within the park.

The northern portion of the park is heavily browsed by deer with strong evidence of extensive deer yards being present. Rooney et al. (2004) noted that native plant populations are adversely affected in protected lands free from deer hunting. This may help explain why there was no evidence of forest regeneration of species described by Curtis (1959) as associates found in the boreal forest such as white cedar. Subcanopy and ground cover species have also been significantly impoverished in northern plant communities of Wisconsin over the past 50 years in areas of high deer populations (Rooney et al. 2004).

Whittelsey (1852), an early explorer, noted that American yew (*Taxus canadensis*) blanketed the ground and was a continued annoyance of the traveler. This plant was observed and collected by John W. Thomson in 1942 from an unspecified location within the park (specimen located at the University of Wisconsin – Superior Herbarium). However, yew was not located during this study, possibly because of the high deer population. This observation has also been made in other parts of Wisconsin as well. Additional authors, such as Stearns (1951) and Alverson et al. (1988) concluded that the lack of yew in forests they were working in was caused by heavy pressures from winter deer populations. Locally, at Pattison State Park (20 km to the southwest) yew is only observed in the most precarious locations of the Black River gorge.

Along with changes to the native plant populations caused by deer, introduced and invasive plants (mostly from Eurasia) have increasingly become a problem throughout Wisconsin. Introduced plants made up 13% of the overall flora found at AFSP. The areas that had the least amount of disturbance also had the lowest incidence of introduced species. The highest concentrations of introduced species were located adjacent to the county road surrounding the park and the pipeline that bisects the park. Personnel at the park have indicated that they would like to see this right-of-way narrowed in future years, which could reduce the amount of introduced and invasive plant seed. Another area with a much lower concentration of introduced species was found in the early succession aspen/birch forest. This area, at the northern end of the park, was farmland prior to the 1960s and several pioneer invasive species (*Trifolium spp. Poa spp. and Agrostis sp.*) occurred in this region. As the forest community matures and moves to a later sere, these pioneer species should continue to decline.

One of the exciting results of the survey work conducted at the park was the observation of 15 new county records, two of which were species of Special Concern (*Geum macrophyllum* and *Scirpus georgianus*). In addition, the project recorded another 15 species that have not been documented in the county in more than 30 years. These findings demonstrate the need for floristic surveys and the gap that exists in species distribution within Wisconsin. Of these 30 species, only *Polygonatum biflorum, Ranunculus sceleratus, Sanicula canadensis,* and *Smilax ecirrhata* had multiple populations within the park. For many species, these observations represent range extensions within Wisconsin. Two of the taxa (*Pedicularis lanceolata* and *Quercus* × *bebbiana*) were observed well beyond their documented range within the state.

As a result of the flora and plant communities documented at Amnicon Falls State Park, numerous possibilities for future research exist. These opportunities include: 1) invasive plant population monitoring (including the threats to native populations), 2) effects of global climate change on forests of northern Wisconsin, 3) impacts of forest activities on native plant populations in the park, 4) impacts of the deer population on the forest understory 5) on-going monitoring of the narrow, but extensive black ash swamps at the northern end of the park (including impacts from the invasive emerald ash borer, currently not present, but a future threat), and 6) to serve as a comparison for future floristic research within the park and surrounding area.

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APPENDIX I: AMNICON FALLS STATE PARK FLORA LIST

The following list is organized alphabetically by family, genus, and then species in each major group of plants. All collections are made by Hlina and Anderson and are deposited at the John W. Thomson Herbarium at the University of Wisconsin – Superior, Superior, Wisconsin (SUWS). Each species is followed by a common name and collection numbers. Introduced species are indicated with an asterisk. Nomenclature follows the published volumes of the Flora of North America (1993+). When the Flora of North America was not available, Wetter et al. (2001) was used for nomenclature.

PTERIDOPHYTES

DENNSTAEDTIACEAE (Bracken Family)

Pteridium aquilinum (L.) Kuhn. var. *latiusculum* (Desv.) Underw. ex A. Heller, bracken fern (86, 88)

DRYOPTERIDACEAE (Wood Fern Family)

Athyrium filix-femina (L.) Roth ex. Mert. var. *angustum* (Willd.) G. Lawson, lady fern (50, 179, 197, 234)

Cystopteris fragilis (L.) Bernh., brittle bladder fern (59, 676, 715, 829)

C. laurentiana (Weath.) Blasdell, Laurentian bladder fern (69, 713, 827, 922, 1125)

Dryopteris carthusiana (Vill.) H.P. Fuchs., spinulose wood fern (49, 820, 920, 921)

D. cristata (L.) A. Gray, crested shield fern (205, 300, 301, 773)

D. fragrans (L.) Schott, fragrant fern (44)

Gymnocarpium dryopteris (L.) Newman, oak fern (87, 89, 461)

Matteuccia struthiopteris (L.) Todaro var. *pensylvanica* (Willd.) C. V. Morton, ostrich fern (648, 668)

Onoclea sensibilis L., sensitive fern (90, 107, 172, 441)

Woodsia ilvensis (L.) R.Br., rusty cliff fern (45, 169, 599, 1003)

EQUISETACEAE (Horsetail Family)

Equisetum arvense L., common horsetail (378, 379, 561, 639)

E. fluviatile L., river horsetail (536)

E. sylvaticum L., wood horsetail (108, 603)

LYCOPODIACEAE (Club-moss Family)

Huperzia lucidula (Michx.) Trevis., shining club-moss (799)

OSMUNDACEAE (Royal Fern Family)

Osmunda cinnamomea L., cinnamon fern (1122, 1127)

O. claytoniana L., interrupted fern (85, 118, 222, 923)

POLYPODIACEAE (Polypody Family)

Polypodium virginianum L., common polypody fern (407, 543)

THELYPTERIDACEAE (Marsh Fern Family)

Phegopteris connectilis (Michx.) Watt, narrow beech fern (150, 255, 443, 447)

GYMNOSPERMS

CUPRESSACEAE (Cypress Family)

Juniperus communis L. var. *depressa* Pursh, common juniper (152, 163)
Thuja occidentalis L., northern white cedar (145, 162)

PINACEAE (Pine Family)

Abies balsamea (L.) Mill., balsam fir (92, 93)
Picea glauca (Moench) Voss, white spruce (6, 525, 604)
Pinus banksiana Lamb., jack pine (642)
P. resinosa Aiton, red pine (986)
P. strobus L., eastern white pine (551, 552)

DICOTYLEDONS

ACERACEAE (Maple Family)

Acer negundo L., box-elder (1129)
A. rubrum L. var. *rubrum*, red maple (41, 42, 304, 305)
A. saccharinum L., silver maple (559)
A. saccharum Marshall var. *saccharum*, sugar maple (10, 787)
A. spicatum Lam., mountain maple (215, 483, 533, 712)

ANACARDIACEAE (Cashew, Sumac Family)

Rhus hirta (L.) Sudw., staghorn sumac (319, 498, 499)
Toxicodendron rydbergii (Small ex Rydb.) Greene, poison ivy (photo)

APIACEAE (Carrot Family)

Angelica atropurpurea L., purple-stem angelica (362)
Cicuta maculata L., common water-hemlock (160, 486, 756)
Heracleum lanatum Michx., American cow-parsnip (photo)
Hydrocotyle americana L., marsh pennywort (242, 892, 972)
Osmorhiza longistylis (Torr.) DC., smooth sweet cicely (147)
Sanicula canadensis L., Canadian black snakeroot (832)
S. marilandica L., black snakeroot (455, 702, 709)
Sium suave Walter, water parsnip (865, 905, 907)

APOCYNACEAE (Dogbane Family)

Apocynum androsaemifolium L., spreading dogbane (76, 193, 253, 426)

AQUIFOLIACEAE (Holly Family)

Ilex verticillata (L.) A. Gray, common winterberry (189, 422, 591, 740)

ARALIACEAE (Ginseng Family)

Aralia nudicaulis L., wild sarsaparilla (74, 75, 123, 649)
A. racemosa L., American spikenard (143, 223, 224, 990)
Panax trifolius L., dwarf ginseng (1121)

ARISTOLOCHIACEAE (Birthwort Family)

Asarum canadense L., wild-ginger (496)

ASCLEPIADACEAE (Milkweed Family)

Asclepias incarnata L. ssp. *incarnata*, swamp milkweed (397, 398, 399, 400)
A. syriaca L., common milkweed (183)

ASTERACEAE (Aster Family)

Achillea millefolium L., yarrow (194, 262, 351, 696)
Ambrosia artemisiifolia L., common ragweed (328)
Anaphalis margaritacea (L.) Benth. & Hook.f., pearly everlasting (29, 131, 132)
Antennaria howellii Greene ssp. *canadensis* (Greene) R. J. Bayer, Howell's pussy-toes (806)
A. neglecta Greene, field pussy-toes (261, 1052)
Artemisia serrata Nutt., saw-tooth wormwood (368)

Bidens cernua L., nodding beggar-ticks (220, 263, 1055, 1056)
B. discoidea (Torr. & A. Gray) Britton, swamp beggar-ticks (1058, 1066)
B. vulgata Greene, tall beggar-ticks (1059)
**Cirsium arvense* (L.) Scop., Canada thistle (355, 361, 890)
C. muticum Michx., swamp thistle (588, 745, 903)
Doellingeria umbellata (Mill.) Nees, flat-top aster (236, 334, 494)
Erigeron philadelphicus L. common fleabane (882, 1053)
E. strigosus Muhl. ex Willd, daisy fleabane (164, 861, 1054, 1062)
Eurybia macrophylla (L.) Cass., big-leaved aster (30, 31, 989, 993)
Eupatorium perfoliatum L., boneset (860)
Eutrochium maculatum (L.) Lamont, spotted Joe-Pye-weed (175, 353, 489, 677)
**Gnaphalium uliginosum* L., low cudweed (323, 350)
Helianthus giganteus L., giant sunflower (1043, 1044, 1045)
H. hirsutus Raf., rough sunflower (1061)
**H. maximiliani* Schrad., Maximilian's sunflower (1046, 1047)
Heliopsis helianthoides (L.) Sweet, ox-eye (1049)
**Hieracium aurantiacum* L., devil's-paintbrush (19, 763)
**H. caespitosum* Dumort., field hawkweed (20 765)
H. scabrum Michx., rough hawkweed (732, 825, 1057)
H. umbellatum L., Canada hawkweed (140, 427, 1064, 1065)
Lactuca biennis (Moench) Fernald, tall blue lettuce (887, 1048)
L. canadensis L., Canada lettuce (1042, 1063)
**Leucanthemum vulgare* Lam., ox-eye daisy (182, 359)
**Matricaria discoidea* DC., pineapple-weed (968)
**M. recutita* L., chamomile (869)
Packera aurea (L.) A. Löve & D. Löve (797)
Petasites frigidus (L.) Fr. var. *palmatus* (Aiton) Cronquist, Arctic sweet colt's-foot (264, 477, 678)
P. frigidus (L.) Fr. var. *sagittatus* (Banks ex. Pursh) Chern., arrowhead sweet colt's foot (1130)
Prenanthes alba L., white-lettuce (22, 137, 448, 1010)
Rudbeckia hirta L. var. *pulcherrima* Farw., black-eyed Susan (352, 497, 500, 873)
Solidago canadensis L., Canada goldenrod (photo)
S. flexicaulis L., zigzag goldenrod (988)
S. gigantea Aiton, giant goldenrod (128, 321, 1072, 1073)
**Sonchus arvensis* L. ssp. *arvensis*, field sow-thistle (414, 924)
Symphyotrichum ciliolatum (Lind.) A. Löve & D. Löve, northern heart-leaved aster (267, 401)
S. cordifolium (L.) G. L. Nesom, arrow-leaved aster (430, 698, 1060, 1067)
S. lanceolatum (Willd.) G. L. Nesom, white panicled aster (149, 535, 1006, 1071)
S. lanceolatum (Willd.) G. L. Nesom var. *interior* (Wieg.) G. L. Nesom, white panicled aster (1070)
S. lateriflorum (L.) A. Löve & D. Löve, calico aster (326, 356, 1008, 1076, 1079)
S. pilosum (Willd.) G. L. Nesom var. *pringlei* (A. Gray) G. L. Nesom, frost aster (249, 1007)
S. puniceum (L.) A. Löve & D. Löve, purple-stemmed aster (1005, 1069, 1074, 1080)
**Tanacetum vulgare* L., common tansy (176, 335, 348, 418)
**Taraxacum officinale* F. H. Wiggers, common dandelion (601)

BALSAMINACEAE (Touch-me-not, Jewelweed Family)
Impatiens capensis Meerb., orange jewelweed (188, 403, 445)

BERBERIDACEAE (Barberry Family)
**Berberis thunbergii* DC, Japanese barberry (243)
Caulophyllum thalictroides (L.) Michx., blue cohosh (952)

BETULACEAE (Birch Family)
Alnus incana (L.) Moench ssp. *rugosa* (Du Roi) R.T.Clausen, speckled alder (97)
A. viridis (Vill.) DC. ssp. *crispa* (Aiton) Turrill, green alder (Photo)

Betula alleghaniensis Britton, yellow birch (98)
B. papyrifera Marshall, white birch (99, 248, 331, 695)
Corylus cornuta Marshall ssp. *cornuta*, beaked hazelnut (100, 101)
Ostrya virginiana (Mill.) K.Koch, ironwood (423, 424, 485, 784)

BORAGINACEAE (Borage Family)
Cynoglossum boreale Fernald., northern wild comfrey (191, 269, 701, 768)
**Myosotis scorpioides* L., common forget-me-not (953, 1050)

BRASSICACEAE (Mustard Family)
**Barbarea vulgaris* R.Br., yellow-rocket (315, 733)
Cardamine pensylvanica Muhl. ex Willd., Pennsylvania bittercress (609, 638, 757)
Rorippa palustris (L.) Besser., common yellow cress (726, 901)

CALLITRICHACEAE (Water-Starwort Family)
Callitriche palustris L., common water starwort (460)

CAMPANULACEAE (Bellflower, Bluebell Family)
Campanula aparinoides Pursh, marsh bellflower (354, 681)

CANNABACEAE (Hemp Family)
Humulus lupulus L. var. *lupuloides* E. Small, common hop (210, 475)

CAPRIFOLIACEAE (Honeysuckle Family)
Diervilla lonicera Mill., northern bush-honeysuckle (80, 871)
Linnaea borealis L. ssp. *americana* (Forbes) Hultén ex R. T. Clausen, twinflower (81, 151, 808)
Lonicera canadensis W.Bartram ex Marshall, American fly honeysuckle (794, 818, 834)
L. dioica L., red honeysuckle (428)
L. hirsuta Eaton, hairy honeysuckle (458, 699)
Sambucus canadensis L. var. *canadensis*, American elderberry (257, 711)
Viburnum lentago L., nannyberry (3, 23, 314, 982)
V. opulus L. ssp. *trilobum* (Marshall) R. T. Clausen, American cranberry-bush (24, 129)
V. rafinesquianum Schult., arrow-wood (25, 492, 520)

CARYOPHYLLACEAE (Pink Family)
**Cerastium fontanum* Baumg. ssp. *vulgare* (Hartm.) Greuter & Burdet, common chickweed (102, 103)
**Dianthus armeria* L., Deptford pink (1107)
**Silene noctiflora* L., night flowering catchfly (259)
**Stellaria graminea* L., common stitchwort (photo)

CONVOLVULACEAE (Morning-glory Family)
Calystegia sepium (L.) R.Br., hedge bindweed (258)

CORNACEAE (Dogwood Family)
Cornus canadensis L., bunchberry (148, 542, 565, 660)
C. racemosa Lam., gray dogwood (38, 228, 944)
C. rugosa Lam., round-leaved dogwood (5, 256, 318)
C. stolonifera Michx., red osier dogwood (39, 40, 478, 802)

CUCURBITACEAE (Cucumber, Gourd Family)
Echinocystis lobata (Michx.) Torr. & A. Gray, wild cucumber (526, 976)

ELAEAGNACEAE (Oleaster Family)
Shepherdia canadensis (L.) Nutt., russet buffalo-berry (82, 124, 522, 833)

ERICACEAE (Heath Family)
Arctostaphylos uva-ursi (L.) Spreng., bearberry (139)
Gaultheria procumbens L., wintergreen (252, 450)
Vaccinium angustifolium Aiton, early low blueberry (104, 452, 456, 547)
V. myrtilloides Michx., Canada blueberry (235)

FABACEAE (Pea Family)
Amphicarpaea bracteata (L.) Fernald, hog-peanut (207, 462)
**Coronilla varia* L., crown-vetch (317, 367, 879)
Desmodium canadense (L.) DC., Canada tick-trefoil (329)
Lathyrus ochroleucus Hook., cream pea-vetch (388, 390, 595, 659)
L. venosus Muhl. ex Willd., forest pea (391)
**Lotus corniculata* L., bird's-foot trefoil (157, 381, 464)
**Medicago sativa* L., alfalfa (524)
**Melilotus alba* Medik., white sweet-clover (165, 878)
**Trifolium arvense* L., rabbit-foot clover (966)
**T. aureum* Pollich, golden clover (977)
**T. hybridum* L., alsike clover (528, 529)
**T. pratense* L., red clover (502, 545)
**T. repens* L., white clover (178)
Vicia americana Muhl. ex Willd. ssp. *americana*, American vetch (384, 686, 706, 835)

FAGACEAE (Beech Family)
Quercus ellipsoidalis E. J. Hill, northern pin oak (299, 641, 853)
Q. macrocarpa Michx., bur oak (127, 296, 297)
Q. rubra L. northern red oak (295, 298, 703, 961)
Q. x bebbiana C.K. Schneid., Bebb's oak (770, 1009, 1041)

FUMARIACEAE (Bleeding-heart, Fumitory Family)
Corydalis aurea Willd. ssp. *aurea*, golden corydalis (836)

GENTIANACEAE (Gentian Family)
Halenia deflexa (Sm.) Griseb. ssp. *deflexa*, American spurred-gentian (109)

GERANIACEAE (Geranium Family)
Geranium bicknellii Britton var. *bicknellii,* Bicknell's cranebill (307)
G. maculatum L., wild geranium (1123)

GROSSULARIACEAE (Gooseberry Family)
Ribes americanum Mill., American black currant (582, 708, 744, 848)
R. cynosbati L., eastern prickly gooseberry (153, 640, 738)
R. hirtellum Michx., hairy-stem gooseberry (231, 682, 771)
R. lacustre (Pers.) Poir., bristly black current (934)
R. triste Pall., swamp red currant (429, 870, 927, 1119)

HYPERICACEAE (St. John's Wort Family)
**Hypericum perforatum* L., common St. John's wort (404, 506, 866)
H. pyramidatum Aiton., giant St. John's wort (635, 915)

LAMIACEAE (Mint Family)
**Galeopsis tetrahit* L. var. *bifida* (Boenn.) Lej. & Courtois, hemp-nettle (537)
Lycopus americanus Muhl. ex W.P.C.Barton, American water-horehound (120, 219, 349, 978)
L. uniflorus Michx., northern bugleweed (208)
Mentha arvensis L. var. *canadensis* (L.) Kuntze, field mint (209, 327, 479, 929)
Prunella vulgaris L. ssp. *lanceolata* (W. P. C. Barton) Hultén, heal-all (77, 587)
Scutellaria galericulata L., common skullcap (468, 476)
S. lateriflora L., blue skullcap (720, 721)
Stachys palustris L., marsh hedge-nettle (330, 519, 874, 1051)
S. tenuifolia Willd. var. *tenuifolia*, narrow-leaved hedge nettle (167)

LYTHRACEAE (Loosestrife Family)
**Lythrum salicaria* L., purple loosestrife (564)

MOLLUGINACEAE (Carpetweed Family)
**Mollugo verticillata* L., carpetweed (325)

MONOTROPACEAE (Indian-pipe Family)
Monotropa uniflora L., Indian-pipe (photo)

OLEACEAE (Olive Family)
Fraxinus americana L., white ash (1120)
F. nigra Marshall, black ash (512)
F. pennsylvanica Marshall, green ash (78, 332, 600, 739)

ONAGRACEAE (Evening-primrose Family)
Circaea alpina L. ssp. *alpina*, alpine enchanter's-nightshade (168, 366, 449, 906)
C. lutetiana L. ssp. *canadensis* (L.) Asch. & Magnus (270, 271, 950)
Epilobium angustifolium L. ssp. *circumvagum* Mosquin, fireweed (406)
E. ciliatum Raf. ssp. *ciliatum*, American willow herb (454)
Oenothera biennis L., common evening-primrose (134, 135, 718, 925)
O. villosa Thunb., hairy evening-primrose (211)

OXALIDACEAE (Wood-sorrel Family)
Oxalis dillenii Jacq., southern yellow wood-sorrel (240, 260, 567, 958)
O. stricta L., tall wood-sorrel (photo)

PAPAVERACEAE (Poppy Family)
Sanguinaria canadensis L., bloodroot (159, 689, 843)

PLANTAGINACEAE (Plantain Family)
Plantago major L., common plantain (341, 394, 911)

POLYGONACEAE (Smartweed Family)
Fallopia cilinodis (Michx.) Holub., black-fringed bindweed (891)
**F. convolvulus* (L.) A. Löve, false buckwheat (photo)
F. scandens (L.) Holub., climbing false buckwheat (482)
**Persicaria hydropiper* (L.) Spach, marsh-pepper knotweed (572, 590, 998)
P. lapathifolia (L.) Gray, curly-top knotweed (582, 645, 999, 1000)
P. pensylvanica (L.) M. Gomez, Pennsylvania knotweed (577, 997, 1002)
P. punctata (Elliott) Small, dotted smarteweed (439, 573, 727)
P. sagittata (L.) H. Gross, arrow-leaved tear-thumb (112, 575, 932, 1001)
Rumex crispus L., curly dock (322)
R. orbiculatus A.Gray, great water dock (364)

PRIMULACEAE (Primrose Family)
Lysimachia ciliata L., fringed loosestrife (130, 365, 405, 598)
L. terrestris (L.) Britton, Sterns, & Poggenb., swamp-candles (32, 472, 761, 881)
Trientalis borealis Raf. ssp. *borealis*, American starflower (453, 655)

PYROLACEAE (Shin-leaf Family)
Chimaphila umbellata (L.) W. P. C. Barton ssp. *cisatlantica* (S.F.Blake) Hultén, pipsissewa (195, 487, 521)
Pyrola asarifolia Michx. ssp. *asarifolia*, pink shin-leaf (196, 584)
P. elliptica Nutt., elliptic shin-leaf (105, 302, 420, 585)
P. rotundifolia L. ssp. *americana* (Sweet) R. T. Clausen, round-leaved shin-leaf (786)

RANUNCULACEAE (Buttercup Family)
Actaea rubra (Aiton) Willd., red baneberry (444, 463, 544, 650)
Anemone americana (DC.) H. Hara, round-lobed hepatica (192, 201, 687)
A. canadensis L., Canada anemone (766, 796)
A. quinquefolia L. var. *quinquefolia*, wood anemone (94, 339, 620, 723)
A. virginiana L., tall anemone (14, 504, 505, 541)
Aquilegia canadensis L., Canadian columbine (251, 576, 693)
Caltha palustris L., marsh-marigold (614, 667)
Clematis occidentalis (Hornem.) DC. var. *occidentalis*, purple clematis (710, 760)
C. virginiana L., virgin's-bower (518, 862, 991)
Ranunculus abortivus L., little-leaf buttercup (652, 838)
**R. acris* L., common buttercup (95, 306, 308, 560)
R. hispidus Michx., bristly buttercup (96, 729, 746)
R. hispidus Michx. var. *caricetorum* (Greene) T. Duncan, bristly buttercup (246, 254, 867)

R. hispidus Michx. var. *hispidus,* bristly buttercup (793)
R. hispidus Michx. var. *nitidus* (Chapm.) T.Duncan, bristly buttercup (245, 247, 902)
R. pensylvanicus L.f., Pennsylvania buttercup (717, 724, 872)
R. recurvatus Poir. var. *recurvatus*, hooked buttercup (631, 775, 840, 912)
R. sceleratus L., celery leaf buttercup (672, 839, 955, 956)
Thalictrum dasycarpum Fisch. & Avé-Lall., tall meadow-rue (116, 569, 747)
T. dioicum L., early meadow-rue (440, 728, 762, 868)

RHAMNACEAE (Buckthorn Family)
**Rhamnus cathartica* L., common buckthorn (842, 962, 964)

ROSACEAE (Rose Family)
Agrimonia gryposepala Wallr., common agrimony (33, 200, 336)
Amelanchier arborea (F. Michx.) Fernald., downy juneberry (546, 625, 627)
A. interior Nielsen, inland juneberry (311, 566)
A. laevis Wiegand, Allegheny serviceberry (190, 626)
A. sanguinea (Pursh) DC. var. *sanguinea*, New England serviceberry (125, 312, 503, 562)
A. spicata (Lam.) K. Koch, dwarf serviceberry (1117)
Comarum palustre L., marsh cinquefoil (216)
Crataegus chrysocarpa Ashe, fireberry hawthorn (510)
C. succulenta Schrad. ex Link, fleshy hawthorn (568)
C. sp., hawthorn (737, 783)
Fragaria vesca L. ssp. *americana* (Porter) Staudt, woodland strawberry (523)
F. virginiana Duchesne, wild strawberry (26, 480)
Geum aleppicum Jacq., yellow avens (126, 181, 313, 643)
G. canadense Jacq., white avens (909, 960)
G. macrophyllum Willd., big leaved avens (309, 606)
Potentilla norvegica L., Norwegian cinquefoil (27, 769)
Prunus americana Marshall, American plum (623, 624)
P. pensylvanica L. f., pin cherry (628, 629, 674, 675)
P. virginiana L. var. *virginiana*, chokecherry (226, 227)
Rosa acicularis Lindl. ssp. *sayi* (Schwein.) W. H. Lewis, bristly rose (1, 457, 644, 807)
R. blanda Aiton, smooth rose (459, 916)
Rubus allegheniensis Porter ex L. H. Bailey, common blackberry (34, 340, 511)
R. idaeus L. var. *strigosus* (Michx.) Maxim., red raspberry (35, 119, 303)
R. parviflorus Nutt., thimbleberry (36, 337, 466)
R. pubescens Raf., dwarf red raspberry (37, 539, 984)
**Sorbus aucuparia* L., Eurasian mountain ash (241)
Spiraea alba Du Roi var. *alba*, white meadowsweet (144, 431, 917)
Waldsteinia fragarioides (Michx.) Tratt. ssp. *fragarioides*, barren strawberry (613, 662)

RUBIACEAE (Bedstraw, Madder Family)
Galium asprellum Michx., rough bedstraw (748, 940, 980, 981)
G. labradoricum (Wiegand) Wiegand, Labrador marsh bedstraw (508)
G. tinctorium L., southern three-lobed bedstraw (507)
G. trifidum L. ssp. *trifidum*, northern three-lobed bedstraw (719)
G. triflorum Michx., fragrant bedstraw (122, 571, 694, 876)
Mitchella repens L., partridgeberry (402)

SALICACEAE (Willow Family)
Populus balsamifera L. ssp. *balsamifera*, balsam poplar (408, 684)
P. grandidentata Michx., big-tooth aspen (432, 819)
P. tremuloides Michx., quaking aspen (4)
Salix bebbiana Sarg., beaked willow (622)
S. discolor Muhl., pussy willow (632, 809, 810, 1016)
S. eriocephala Michx., diamond willow (1026, 1027)
S. exigua Nutt. ssp. *interior* (Rowlee) Cronquist, sandbar willow (177, 1029, 1030, 1040)
S. humilis Marshall, upland willow (1033, 1034, 1035, 1036)
S. lucida Muhl. ssp. *lucida*, shining willow (631, 736, 1025)

S. petiolaris Sm., meadow willow (1012, 1013, 1015, 1031)
**S. x rubens* Schrank (pro sp.), hybrid crack willow (415, 530, 531)

SAXIFRAGACEAE (Saxifrage Family)
Penthorum sedoides L., ditch stonecrop (250, 889, 970, 969)
Saxifraga pensylvanica L., eastern swamp saxifrage (474, 679)

SCROPHULARIACEAE (Figwort, Snapdragon Family)
Chelone glabra L., turtlehead (photo)
Melampyrum lineare Desr., narrow-leaved cow-wheat (185)
Mimulus ringens L. var. *ringens*, monkey-flower (142, 434, 983)
Pedicularis lanceolata Michx., swamp betony (106, 824)
Scrophularia lanceolata Pursh, American figwort (237, 238, 239)
**Verbascum thapsus* L., common mullein (324)
**Veronica serpyllifolia* L., thyme-leaved speedwell (734, 735)

SOLANACEAE (Nightshade Family)
Solanum dulcamara L., bittersweet nightshade (141, 515)

TILIACEAE (Linden Family)
Tilia americana L. var. *americana*, American basswood (436)

ULMACEAE (Elm Family)
Ulmus americana L., American elm (749, 785)

URTICACEAE (Nettle Family)
Laportea canadensis (L.) Wedd., Canadian wood-nettle (photo)
Pilea pumila (L.) A.Gray, Canadian clearweed (1126)
Urtica dioica L. ssp. *gracilis* (Aiton) Selander, stinging nettle (1124)

VALERIANACEAE (Valerian Family)
**Valeriana officinalis* L., garden valerian (9, 28, 173, 481)

VERBENACEAE (Vervain Family)
Verbena hastata L., blue vervain (154, 435)

VIOLACEAE (Violet Family)
Viola cucullata Aiton, blue marsh violet (553, 579, 581)
V. labradorica Schrank, dog violet (7, 554, 612, 653)
V. novae-angliae House, New England blue violet (822)
V. pubescens Aiton, downy yellow violet (12, 333, 570, 656)
V. sororia Willd., door-yard violet (580, 605, 670, 963)

VITACEAE (Grape Family)
Parthenocissus quinquefolia (L.) Planch., Virginia creeper (437, 722)
P. vitacea (Knerr) Hitchc., grape woodbine (204)

MONOCOTYLEDONS

ALISMATACEAE (Water-plantain Family)
Alisma subcordatum Raf., common water plantain (113, 908)
A. triviale Pursh, northern water plantain (17, 202, 596)
Sagittaria latifolia Willd., broad-leaved arrowhead (221, 634, 904)

ARACEAE (Arum Family)
Arisaema triphyllum (L.) Schott. ssp. *triphyllum*, jack-in-the-pulpit (446, 615)
Calla palustris L., water-arum (469)

CYPERACEAE (Sedge Family)
Carex aquatilis Wahlenb., water sedge (287)
C. arctata Boott ex Hook., drooping wood sedge (800, 812, 813)
C. bebbii (L. H. Bailey) Olney ex Fernald, Bebb's sedge (897)
C. brunnescens (Pers.) Poir. ssp. *sphaerostachya* (Tuck.) Kalela, brownish sedge (294)
C. castanea Wahlenb., chestnut sedge (285, 286, 690, 945)

C. crawfordii Fernald, Crawford's sedge (774, 1114)
C. crinita Lam. var. *crinita*, fringed sedge (283, 473, 893)
C. debilis Michx. var. *rudgei* L. H. Bailey, northern weak sedge (282)
C. deflexa Hornem. var. *deflexa*, northern oak sedge (666)
C. deweyana Schwein. var. *deweyana*, Dewey's sedge (610, 754)
C. gracillima Schwein., graceful sedge (281, 292, 755, 795)
C. intumescens Rudge, greater bladder sedge (279, 280, 345)
C. lacustris Willd., common lake sedge (777, 933)
C. merritt-fernaldii Mack., Fernald's sedge (943)
C. ormostachya Wiegand, necklace-spike sedge (1118)
C. pedunculata Muhl. ex Willd., long stalked sedge (611)
C. projecta Mack., loose-headed oval sedge (646, 928, 931, 939, 1115)
C. radiata (Wahlenb.) Small, eastern star sedge (859)
C. retrorsa Schwein., deflexed bottlebrush sedge (346, 357, 369, 886, 992)
C. stipata Muhl. ex Willd. var. *stipata*, common fox sedge (289, 290, 291, 791, 936)
C. tonsa (Fernald) E. P. Bicknell, shaved sedge (805)
C. tuckermanii Dewey, bent-seeded hop sedge (370, 371, 372, 373, 898)
C. vesicaria L., blister sedge (374, 772, 930)
C. vulpinoidea Michx., brown fox sedge (514)
Eleocharis obtusa (Willd.) Schult., blunt spike rush (557, 883, 888)
E. ovata (Roth) Roem. & Schult., oval spike rush (344, 558)
E. palustris (L.) Roem. & Schult., common spike rush (556)
Schoenoplectus pungens (Vahl) Palla, chair-maker's rush (790)
S. tabernaemontani (C. C. Gmel) Palla, great bulrush (380, 789)
Scirpus atrocinctus Fernald., black-girdled wool-grass (788)
S. atrovirens Willd., black bulrush (967, 974)
S. cyperinus (L.) Kunth., wool-grass (358, 488)
S. georgianus R. M. Harper, Georgia bulrush (594)
S. hattorianus Makino, early dark green bulrush (633)
S. microcarpus J. Presl & C. Presl, panicled bulrush (121, 375)

IRIDACEAE (Iris Family)
Iris versicolor L., northern blue flag (187, 360, 490)

JUNCACEAE (Rush Family)
Juncus brevicaudatus (Engelm.) Fernald, narrow-panicle rush (1113)
J. effusus L., common rush (376)
J. nodosus L., joint rush (377, 885)
J. vaseyi Engelm., Vasey's rush (1128)
Luzula acuminata Raf. var. *acuminata*, hairy wood rush (616, 654)
L. multiflora (Ehrh.) Lej. ssp. *multiflora*, common wood rush (409, 823)

LEMNACEAE (Duckweed Family)
Lemna minor L. common duckweed (212)

LILIACEAE (Lily Family)
**Asparagus officinalis* L., asparagus (156, 264)
Clintonia borealis (Aiton) Raf., yellow blue-bead-lily (170, 206, 467)
**Convallaria majalis* L. var. *majalis*, lily-of-the-valley (841)
Erythronium americanum Ker Gawl. ssp. *americanum*, yellow trout lily (673)
Lilium michiganense Farw., Michigan lily (593, 884, 971)
Maianthemum canadense Desf., wild lily-of-the-valley (15, 199, 213, 538)
M. racemosum (L.) Link ssp. *racemosum*, false Solomon's-seal (636)
M. trifolium (L.) Sloboda, false mayflower (198, 680)
Polygonatum biflorum (Walter) Elliott, king Solomon's-seal (416)
P. pubescens (Willd.) Pursh., downy Solomon's-seal (110, 421, 602)
Streptopus lanceolatus (Aiton) Rev., rosy twisted-stalk (661, 664, 831)
Trillium cernuum L., nodding trillium (8, 83, 342, 657)
Uvularia grandiflora Sm., large-flowered bellwort (11, 184, 410, 413)

U. sessilifolia L., sessile bellwort (603, 637, 671)

ORCHIDACEAE (Orchid Family)

Cypripedium parviflorum Salisb. var. *makasin* (Farw.) Sheviak, small yellow lady's-slipper (photo)

Platanthera psycodes (L.) Lindl., lesser purple fringed orchid (465)

POACEAE (Grass Family)

**Agrostis gigantea* Roth, redtop (1086)

Alopecurus aequalis Sobol., short-awned foxtail (913)

Brachyelytrum aristosum (Michx.) Trel., bearded shorthusk (1096)

B. erectum (Schreb. ex Spreng.) P. Beauv., long-awned wood grass (1097)

Bromus ciliatus L., fringed brome (16, 115, 343, 1101)

Calamagrostis canadensis (Michx.) P. Beauv., blue-joint grass (18)

**Dactylis glomerata* L., orchard grass (826)

Danthonia spicata (L.) P. Beauv. ex Roem. & Schult., poverty oat grass (877)

Dichanthelium acuminatum (Sw.) Gould & C. A. Clark, hairy panic grass (801)

Echinochloa muricata (P. Beauv.) Fernald var. *muricata*, barnyard grass (1102)

Elymus hystrix L. var. *hystrix*, bottlebrush grass (412, 470, 894)

E. virginicus L. var. *virginicus*, Virginia wild-rye (1094)

**Festuca trachyphylla* (Hack.) Krajina, hard fescue (817)

Glyceria canadensis (Michx.) Trin., rattlesnake manna grass (1081)

G. grandis S. Watson, American manna grass (910, 1104, 1111)

G. striata (Lam.) Hitchc., fowl manna grass (1090, 1105)

Leersia oryzoides (L.) Sw., rice cut grass (1001)

Milium effusum L., American millet grass (1099)

Oryzopsis asperifolia Michx., rough-leaved rice grass (617, 663, 688, 1098)

O. pungens (Torr. ex Spreng.) Hitchc., mountain rice grass (804)

Panicum capillare L. ssp. *capillare*, common witch grass (1103)

**Phalaris arundinacea* L., reed canary grass (899, 1083, 1087, 1093)

**Phleum pratense* L. ssp. *pratense*, Timothy (419, 764)

Phragmites australis (Cav.) Trin. ex Steud., common reed (900, 1088, 1089, 1091)

**Poa annua* L., annual bluegrass (1110)

**P. compressa* L., Canada bluegrass (1109)

P. palustris L., marsh bluegrass (880, 1095, 1108, 1112)

**P. pratensis* L., Kentucky bluegrass (8, 106, 161)

Spartina pectinata Link., prairie cord grass (1085)

SMILACACEAE (Cat-brier Family)

Smilax ecirrhata S. Watson, upright carrion flower (438, 548, 776, 863)

S. tamnoides L., bristly greenbrier (146, 174)

SPARGANIACEAE (Bur-reed Family)

Sparganium angustifolium Michx., narrow-leaved bur-reed (1131)

S. emersum Rehmann, narrow-leaved bur-reed (1116)

S. eurycarpum Englm., giant bur-reed (111)

TYPHACEAE (Cat-tail Family)

**Typha angustifolia* L., narrow-leaved cat-tail (842)

T. latifolia L., broad-leaved cat-tail (166, 395, 396)

THE *FERNWORT PAPERS* — HISTORY AND BIBLIOGRAPHY

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Publications on pteridology, especially those on the taxonomy of North American *Isoëtes* and on the distribution and ecology of the rare American hart's-tongue fern, *Asplenium scolopendrium* L. var. *americanum* (Fernald) Kartesz & Gandhi, often cite papers or scientific names published in *Fernwort Papers*. For decades I was unable to locate or even to identify this publication. Citations from *Fernwort Papers* often contain page numbers only, no volume number, as with a book rather than a journal. Otherwise, however, these citations are not in the format used for a book, as they do not include the name of the editor, publisher, or city in which it was published. In other citations the volume number 2 precedes the page numbers for the same papers or plant names, suggesting that *Fernwort Papers* might be a journal. Yet it is not listed in the *Union List of Serials* or in *Botanico-Periodicum-Huntianum*. What, I wondered, is or was *Fernwort Papers*? Were botanical names validly published therein? Are any copies extant?

Some years ago I searched the card catalogues of major botanical libraries, the printed catalogue of the Library of Congress, and other seemingly appropriate references in addition to those mentioned above, but found no mention of *Fernwort Papers*. One botanist who had cited a paper from *Fernwort Papers* was sure that he had seen it in one of two possible libraries (one of which I later found did have it), but at neither library could the staff find any record of it. The late Dr. Warren H. Wagner, Jr., librarian of the American Fern Society at the time, searched the Society's catalogue and other references, but could find nothing on it—and was likewise intrigued by the mystery.

Compilers of electronic library catalogues are entering more information than had ever been in the card catalogues as well as making information more readily retrievable through Boolean searches. When I renewed my search after Internet resources had become available, I found nineteen libraries that hold copies of this long-elusive publication, among which are those of the Gray Herbarium of Harvard University, the Missouri Botanical Garden, the New York Botanical Garden, the University of California at Berkeley, the University of Texas at Austin, and the Royal Ontario Museum.

Fernwort Papers was published by The Linnaean Fern Chapter of the Agassiz Association. In the Chapter's early years, when it was an organization largely of amateurs, it published only those papers that had been presented orally at its meetings. The first meeting at which research papers were presented was held in 1898. The papers, of which there were seven, were pub-

lished in 1899 in a 31-page volume identified as *Papers presented at the Boston meeting, under the auspices of the Linnaean Fern Chapter, August 24, 1898*. The next such meeting was held in 1900. The five papers presented at that meeting were published in a 41-page volume the same year. Its title was similar, but with the addition of the word "fernwort": *Fernwort papers presented at a meeting of fern students held in New York City, July 27, 1900, under the auspices of the Linnaean Fern Chapter*. This was the second volume of papers presented at meetings "under the auspices of the Linnaean Fern Chapter," but it was the first and only volume to bear the title *Fernwort Papers*. Therefore some have regarded it as the second volume of a short-lived serial, by implication with volume numbering continuous through a change of title, whereas others have regarded the two volumes as separate, non-serial publications. In the electronic catalogue of the University of California libraries, for example, the "format" for both is given as "book." In the libraries named above, both of these compendia are present in the first four listed, only the *Fernwort Papers* in the other two.

Both volumes were published by the Linnaean Fern Chapter, which made arrangements for printing with W.N. Clute & Co., of Binghampton, New York. (The word "fernwort" was frequently used by Willard N. Clute, who probably coined it, but rarely by anyone else. It designated the vascular cryptogams collectively, commonly treated in Clute's time as the division Pteridophyta of the Plant Kingdom, and was equivalent to the term "ferns and fern allies" used by many of his contemporaries.) As the Linnaean Fern Chapter had no official headquarters, Binghampton should be considered the place of publication.

Of the two volumes, only the second, entitled *Fernwort Papers*, contains new botanical names. In it, the names *Isoëtes gravesii*, *I. harveyi*, *I. heterospora*, *I. hieroglyphica*, and *I. tuckermanii* var. *borealis* were validly published by A.A. Eaton (1900). Of these, the first two are now accepted as the names of interspecific hybrids; the third and fourth are included in the synonymy of *I. lacustris* L.; and the fifth is included in the synonymy of *I. tuckermanii* A. Braun var. *tuckermanii* (Taylor et al. 1995). Also in this volume, W.R. Maxon (1900) validly published the new combination *Phyllitis Lindenii* [sic] (Hook.) Maxon for the Mexican and West Indian fern now called *Asplenium scolopendrium* L. var. *lindenii* (Hook.) Viane et al. (Wagner et al. 1993).

This study has cleared up some confusion about the name *Osmunda claytoniana* var. *dubia*. In some references this name is attributed to "(Grout) Gilbert," but no basionym is cited. In a paper presented at the Boston meeting, Grout described an unusual variant of *O. claytoniana* L. but did not give it a name. In 1901, in his "Working list of North American pteridophytes (north of Mexico)," Gilbert noted Grout's description of this fern, and said that at his request Grout had "consented to name it." That wording suggests that the epithet *dubia* was chosen by Grout, but no part of the "Working list" is attributed to Grout's authorship. The name *O. claytoniana* [var.] *dubia* was published by Gilbert and should therefore be attributed to "Grout ex Gilbert" or simply to "Gilbert," but not to "(Grout) Gilbert," as there was no basionym.

In 1901 the Linnaean Fern Chapter began publishing a quarterly, *The Linnaean Fern Bulletin*, later called *The Fern Bulletin*, of which the volume num-

bering began with 1. The Chapter subsequently separated from the Agassiz Association and became the American Fern Society, and in 1910 began publishing the *American Fern Journal*. This new journal began with volume 1. *The Fern Bulletin* continued to be published by W.N. Clute & Co. until 1912, when it was absorbed by *The American Botanist*.

ACKNOWLEDGMENTS

I am grateful to the library staff of the Missouri Botanical Garden for access to historic publications. This paper is Contribution No. 187 from the Royal Botanical Gardens, Hamilton, Ontario, Canada.

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NOTEWORTHY COLLECTIONS

INDIANA

Eucommia ulmoides Oliver (Eucommiaceae). Hardy rubber-tree

Previous knowledge.

Eucommia ulmoides Oliver, the sole living member of the genus *Eucommia* Oliver and the family Eucommiaceae, is native to mountain forests in central and western China, in open forests and in valleys, at elevations of 200–2500 m (Ying et al. 1993), and is now rare outside of cultivation (Zhang et al. 2003). It was first introduced into cultivation in Europe in 1892 and the United States in 1896 (Rehder 1947). The species was first reported as an escape in the United States from Ohio (Vincent 2002), and was described, illustrated, and discussed at length in that paper.

Hardy rubber-tree is sometimes used as a street or lawn tree, and has been considered underutilized by some horticulturalists (Dirr 1990, 1997; Gilman 1997; Poor 1997). *Eucommia ulmoides* is listed as hardy in USDA Zones 4–7 (Dirr, 1990, 1997; Poor 1997).

Significance.

Eucommia ulmoides was recently found as an escape in Indianapolis, Marion County, Indiana, in a deciduous broadleaf forest near the Holliday Park Nature Center, on both sides of a small ravine, deep into the forest and up onto a ridge across the ravine. The species was not listed as part of the Indiana flora by Deam (1940), Crovello et al. (1983), or Overlease and Overlease (2007).

The trees observed at this site number somewhere between 75 and 100 individuals, ranging from small saplings (the smallest seen was about 1′ tall, and appeared to be 2 years old) to subcanopy trees ca. 35′ tall. The largest individual (ca. 10″ DBH) had been cut down earlier this year, and was sending out root suckers from the stump. Source plants in the arboretum at the nature center ranged from 200 yards to nearly 0.25 mile from the woods.

Vincent (2002) discussed the invasive potential for hardy rubber-tree, and stated that its potential as an invasive was low, as was also stated by Gilman and Watson (1993). However, the number of individuals at this site indicates that the species may indeed become invasive, especially in areas where it is planted in higher numbers as a lawn or street tree.

Diagnostic characters.

Hardy rubber-tree is easily recognized by its alternate, bright green, glabrous leaves, the latex strands visible in gently torn leaves, and its thick, green samaras.

Voucher specimens.

INDIANA: Marion County: Holliday Park; *Homoya s.n.*, 1984 (herbarium of the Indiana Department of Natural Resources); *Vincent 14,151, with Homoya and Schmid*, 29 Oct 2008 (BKL, BUT, IND, MO, MOAR, MOR, MU, NA, ND, PUL).

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BOOK REVIEW

Curtis, Linda. 2006. *Woodland Carex of the Upper Midwest.* Curtis to the Third Productions, P.O. Box 731, Lake Villa, Il 60046 $19.95, Hard Cover, 3-Ring Binder.

All of us who have done field work have encountered sedges (*Carex*), those moderately easy to distinguish three-sided stemmed clumps of "grass-like" plants with seeds in a sac. It is so easy to recognize most species to the genus but it is so different trying to identify them to the correct species. The author has taken on a difficult task to make identification relatively easy.

To begin with, the book is a loose-leaf one in a three-ring, hard binder with a color photograph of *C. lupulina* on the front cover and four other species on the back. The pages are one-half the standard 8 1/2″ × 11″ letter size sheets with holes on the long side making it easy to take into the field. The book deals with 63 of the over 100 species that grow in dry to wet habitats in the herb layer of Upper Midwest woodlands. Excluded from this field guide are the species of sunny wetlands such as bogs, fens, marshes, open wet prairies or the open sandy dunes along Lake Michigan. Therefore, the user may encounter species not covered by the guide and will have to consult other sources for complete identification.

The book begins with an 18 page discussion of the descriptive terminology applied to sedges. Combining clear, quality, close-up black and white photographs the author deals with seed head patterns, how to tell the male and female flowers apart, the sacs or perigynia, beaks, scales, growth forms of the stems or culms, sheaths, ligules and vein patterns.

The bulk of the book, pages 19–156 is divided into eight sections, with each section concentrating on features of the sac or perigynium. Each section then has a dichotomous key to the species of the section. Each species is illustrated by close-up black and white photographs or sketches of the features needed to properly identify the taxon. Characters distinguishing the species from similar ones are discussed at times in some detail. The wording of the key couplets is simple and clear and I was able to identify three unknown species with ease. However, a fourth species, from a local sandy woods was not in the book making it limited for my part of the Upper Midwest.

The final section of the book includes special keys to species with hairy leaves, narrow leaves, and spikes that are very large and over 3 cm long (called super sedges) and those with small spikes and less than 2 cm long. Page 166 is a list of eight Websites where *Carex* species can be viewed. The Index gives the pages numbers where the 70+ species are mentioned.

The plastic covered pages provide some water resistance when using the book for field identification and its size fits well in a day pack but is too large for a fanny pack.

The author, a retired college teacher, has gained a wealth of field experience with *Carex* and in instructing the public in outdoor botany. This knowledge comes through in the information and layout of the self-published book. If the user remembers the geographic and ecological limits of the work, I believe it has a place on any naturalist's book shelf, and it will be helpful in sedge identification.

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INSTRUCTIONS TO AUTHORS

1. Create text in 12-point Times New Roman font and double space paragraphs throughout. Papers should be organized as follows: Title, Author(s) and address(es), Abstract with up to 5 keywords, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, Literature Cited, Tables, Figure Legends, and Figures. Sections may be omitted if not relevant. All pages should be numbered. Please contact the editor regarding any questions related to formatting.

2. For noteworthy collections, manuscripts should be formatted as described in *The Michigan Botanist*, volume 27(3) p. 90. A brief description of the formatting follows. The following title, "Noteworthy collections", should begin each submitted manuscript followed on the next line by the State or Province for the species reported. The next line should list the taxon of interest using the following format: *Species* Author(s) (Family). Common name. The rest of the manuscript should include the following named sections: Previous knowledge, Significance of the report, Diagnostic characters (if desired), Specimen citations, and Literature cited. Each of these sections are largely self explanatory; however, "specimen citations" should include the relevant label data from the voucher specimen(s) including location data, collector(s), collection number, etc. Also please include which herbarium the specimen(s) is deposited in using the Index Herbariorum acronym. The manuscript should end with the name and address of the author(s).

3. Letters to the Editor can be formatted as general text without the specific sections listed above. However, literature cited and any tables or figures should be formatted as described below.

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6. Citations: Please verify that all references cited in the text are present in the literature cited section and vice versa. Citations within the text should list the author's last name and publication year (e. g. Smith 1990). For works with more than 2 authors, use "et al.", and separate multiple citations with a semicolon.

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8. Italicize all scientific names. Voucher specimens must be cited for floristic works or any other relevant study. Papers citing plant records without documenting vouchers are generally not acceptable.

9. Manuscripts may be submitted electronically to the email address of the editor. Printed versions of manuscripts may also be submitted in which case three copies should be provided. All manuscripts will be reviewed by at least two referees. A more complete set of instructions is available at http://www.michbot.org/publications/Botanist/instruct_authors.htm.

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On the cover: *The Amnicon River, Amnicon Falls State Park, Douglas Co., WI. This small river rages in the spring as water from melting snow rushes to Lake Superior. However, by late fall the main source of water for the river is Amnicon Lake, 22 kilometers southwest of the park. The low water level in the fall exposes a river bottom of bedrock and boulders. Photograph taken by Nils Bergman in September 2006.*